6-16-1874

Report upon the reconnaissance of northwestern Wyoming, made in the summer of 1873 by William A. Jones, Captain of Engineers U. S. A.

43D CONGRESS, 1st Session. } HOUSE OF REPRESENTATIVES. { EX. DOC. No. 285.

REPORT

UPON

THE RECONNAISSANCE

OF

NORTHWESTERN WYOMING,

MADE IN

THE SUMMER OF 1873

BY

WILLIAM A. JONES,

CAPTAIN OF ENGINEERS U. S. A.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1874.

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BY DR. C. C. PARRY.

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MAPS.

Map of Western Wyoming, showing region traversed; scale $\frac{1}{600000}$; forty-nine trail-maps, showing detailed topography; geological map, (colored;) scale $\frac{1}{600000}$.

THE CHIEF [illegible] OF THE WAR DEPARTMENT

A report upon [illegible] Montana [illegible]
[illegible] Captain W. A. Jones [illegible]

The C[illegible] of War, [illegible] compliance [illegible] of the House [illegible] reconnaissance [illegible] Captain W. A. Jones, Corps of Engineers, [illegible] year 1[illegible] in [illegible] the Yellowstone [illegible] El[illegible] of the [illegible]

WAR [illegible]

OFFICE OF THE CHIEF OF ENGINEERS,
Washington, D. C., [illegible]

SIR: [illegible] the [illegible] of the 29th [illegible] I have [illegible] hand[illegible] report of a reconnaissance of [illegible] Wyo[illegible] summer of 1873, by Captain W. A. Jones, [illegible] of E[illegible] of the Department of the Platte, [illegible] endo[illegible] commanding that department.

It [illegible] report of Captain Jones that the [illegible] to Montana [illegible] Yellowstone Park, proposed by him, [illegible] route that [illegible] of the Missouri River [illegible] would [illegible] and would prove advantageous [illegible] Government [illegible] of military and Indian supplies.

The route passes the military posts of Camp [illegible] and Camp Brown and the [illegible] Indian agency, and is stated to be the [illegible] and most practicable route to the Yellowstone Park and [illegible] ering a [illegible] and agricultural country in the [illegible] ley; [illegible] the upper [illegible] fertile and [illegible] also a fine agri[illegible] cultural [illegible] the valley of the Yellowstone below the lake.

It would [illegible] to the [illegible] and mineral resources of Montana, [illegible] Captain Jones [illegible] decli[illegible]

H. Ex. [illegible]

LETTER

FROM

THE CHIEF CLERK OF THE WAR DEPARTMENT,

TRANSMITTING

A report upon the reconnaissance of Northwestern Wyoming, made in the summer of 1873 *by Captain William A. Jones, Corps of Engineers.*

The Chief Clerk of the War Department, in the absence of the Secretary of War, has the honor to transmit to the House of Representatives, in compliance with resolution of the House of the 20th ultimo, report of a reconnaissance made by Captain W. A. Jones, Corps of Engineers, in the year 1873, for a wagon-road from the line of the Union Pacific Railroad, in Wyoming Territory, to the Yellowstone National Park and Fort Ellis, Montana Territory, together with letter of the Chief of Engineers, of the 13th instant, transmitting the same.

H. T. CROSBY,
Chief Clerk.

WAR DEPARTMENT, *June* 16, 1874.

OFFICE OF THE CHIEF OF ENGINEERS,
Washington, D. C., June 13, 1874.

SIR: In compliance with the reference to this Office of a resolution of the House of Representatives of the 20th ultimo, I have the honor to transmit herewith a copy of a report of a reconnaissance of Northwestern Wyoming, made in the summer of 1873, by Captain W. A. Jones, Corps of Engineers, chief engineer of the Department of the Platte, under the orders of Brig. Gen. E. O. C. Ord, commanding that department.

It would appear from the report of Captain Jones that the wagon-road to Montana, by the Yellowstone Park, proposed by him, would open a route that, whatever may be the advantages of the Missouri River route, would tend to keep down rates, and would prove advantageous to the Government in the transportation of military and Indian supplies.

The route passes the military posts of Camp Stambaugh and Camp Brown and the Crow Indian agency, and is stated to be the shortest and most practicable route to the Yellowstone Park and Montana; traversing a fine mineral and agricultural country in the Wind River Valley; an extensive area of well-timbered and well-watered country about the upper valleys of the Snake and Yellowstone Rivers, where the soil is fertile and the rain falls equably through the season; and also a fine agricultural country in the valley of the Yellowstone below the falls.

It would give an outlet to the mineral and agricultural resources of Montana, which is stated by Captain Jones to be one of the most productive mining regions of the West; and, in that connection, it is to be noted that this route would save two hundred and fifty miles of railroad transportation, or the distance from Point of Rocks to Corinne, which is the present point of departure on the Union Pacific Railroad for the posts in Montana.

Very respectfully, your obedient servant,

A. A. HUMPHREYS,
Brigadier-General and Chief of Engineers.

Hon. WM. W. BELKNAP,
Secretary of War.

Unexpected delay has occurred in the copying of the maps by which the report is accompanied, and they will be transmitted within a few days.

HEADQUARTERS DEPARTMENT OF THE PLATTE,
OFFICE OF THE ENGINEER OFFICER,
Omaha, Nebr., May 9, 1874.

SIR: I have the honor to transmit herewith my final report upon the military reconnaissance of Northwestern Wyoming, made during the summer of 1873.

I take great pleasure in thanking my associates in the field-work for their uniform courtesy and devotion to duty; the officers of the department staff for their kindly and efficient assistance while I was preparing my outfit for the field; the officers and men of Company I, Second Cavalry, for their constant and willing assistance; Lieut. R. H. Young, Fourth Infantry, for his extremely arduous and efficient services as acting assistant quartermaster and assistant commissary of subsistence for the expedition; and Mr. Charles Curtis, pack-master, for his untiring energy and enthusiastic devotion to duty.

The report is accompanied by the following reports, viz:

Botany, by Dr. C. C. Parry;

Geology, by Professor T. B. Comstock;

Astronomy, by Lieut. S. E. Blunt, Thirteenth Infantry;

Entomology, by J. D. Putnam; and

One map (in the preparation of which valuable information was obtained from the maps of Professor Hayden and Captains Barlow and Heap, United States Engineers) showing the region traversed, and forty-nine trail-maps, showing, on a large scale, the topography along each day's march.

Considering the extremely successful results in that field, the report upon botany is rather more meager than I had anticipated. Ten new species were collected, none of which are described.

Dr. Heizmann's report upon mineral and thermal waters has not yet reached me; delayed, I suppose, by his sickness. It will be transmitted as soon as I receive it.*

In conclusion, permit me, sir, to thank you for your kindly interest and constant and intelligent assistance, to which much of our success must be ultimately attributed.

I am, sir, very respectfully, your obedient servant,

W. A. JONES,
Captain of Engineers.

Brig. Gen. E. O. C. ORD,
Commanding Department of the Platte.

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* Report since received, and is appended hereto.

HEADQUARTERS DEPARTMENT OF THE PLATTE,
Omaha, Nebr., May 11, 1874.

SIR: Captain Jones's report and accompanying maps of an exploration of Northwestern Wyoming are herewith inclosed. He received from me, besides the written instructions stated in the report, verbal directions to find, if possible, a good route from the south, via the Wind River Valley and Upper Yellowstone, into Montana, which the report shows he accomplished.

The trail-maps give a correct and detailed picture of the country passed over; the reports of the geologist and botanist, with Captain Jones's description, explain its resources and capacity to support a large population, and show that the country to the south and west, and in the vicinity of Yellowstone Lake, will not, for agricultural purposes, require irrigation, as does the most of Wyoming and Montana.

Valuable minerals were found, especially in the Wind River and Shoshone Mountains.

The fact that this route, north of the Wind River Valley, passes through a timbered country, over which the mild southwest winds prevail in winter, renders it probable that, even at great elevations, it is not liable to drifting snows. Its shortness compared with the present traveled route via Corinne, the mildness of the climate, fertility of the soil, and abundance of water, coal, wood, &c., in the Wind River Valley, are strong reasons for opening the route for the use of the military posts, and the people of Montana, which section is languishing for the want of an outlet for its valuable mineral and agricultural productions.

I therefore recommend that Congress be asked for an appropriation of $60,000 to open a wagon-road from Camp Brown, or some convenient point on the Union Pacific Railroad, to Fort Ellis, or Helena, Montana.

I am, sir, very respectfully, your obedient servant,

E. O. C. ORD,
Brigadier-General Commanding.

The ADJUTANT-GENERAL UNITED STATES ARMY,
Through Headquarters Military Division
of the Missouri, Chicago, Ill.

[First indorsement.]

HEADQUARTERS MILITARY DIVISION OF THE MISSOURI,
Chicago, May 15, 1874.

Respectfully forwarded to the headquarters of the Army.

P. H. SHERIDAN,
Lieutenant-General Commanding.

[Second indorsement.]

HEADQUARTERS OF THE ARMY,
Washington, May 18, 1874.

Respectfully forwarded to the Adjutant-General.
By command of General Sherman:

WILLIAM D. WHIPPLE,
Assistant Adjutant-General.

[Third indorsement.]

WAR DEPARTMENT, ADJUTANT-GENERAL'S OFFICE,
Washington, May 19, 1874.

Respectfully referred to the Chief of Engineers. *To be returned.*

E. D. TOWNSEND,
Adjutant-General.

CHICAGO, *May* 16, 1874.

COLONEL: The inclosed order* was issued in order to give Capt. William A. Jones, Engineer Corps, a chance to have his work of last summer published; but I wish it to be distinctly understood that I in no manner can indorse the contemplated road from the Point of Rocks, on the Union Pacific Railroad, to Fort Ellis, via Yellowstone Lake, as a military necessity.

If the Government desire to make appropriation for the benefit of the mining population at Atlantic City, and the settlers in and about Camp Brown in the Popo Agie Valley, I have no objection; but I am not prepared to give even a shadow of support to anything so absurd as the military necessity for such a road.

The land-transportation now, via Carroll on the Missouri River, to Fort Ellis is only two hundred and twenty miles, over a good road.

I am, colonel, very respectfully, your obedient servant,

P. H. SHERIDAN,
Lieutenant-General Commanding.

Col. W. D. WHIPPLE,
Assistant Adjutant-General,
Headquarters of the Army, Washington, D. C.

[First indorsement.]

HEADQUARTERS OF THE ARMY,
Washington, May 19, 1874.

Official copy respectfully forwarded to the Secretary of War.

W. T. SHERMAN,
General.

[Second indorsement.]

WAR DEPARTMENT, ADJUTANT-GENERAL'S OFFICE,
Washington, May 20, 1874.

Respectfully referred to the Chief of Engineers, to whom was referred the report of Captain Jones of his explorations in Northwestern Wyoming, on the 19th instant. To be returned.

By order:

E. D. TOWNSEND,
Adjutant-General.

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*Special Order No. 30, Headquarters Military Division of the Missouri, May 15, 1874.

GENERAL REPORT.

CHAPTER I.

DESCRIPTIVE JOURNAL.

Fort Bridger—Pacific Springs—Hostile Indians—South Pass—Sweetwater River—Camp Stambaugh—Camp Brown—Shoshonee agency—Hot Sulphur Spring—Wind River—Owl Creek Mountains—Valley of the Big Horn—Discovery of the Sierra Shoshonee—Ascent of the Washakee Needles—Shoshonee Village—Washakee—Indian Scouts—Stinkingwater River—Crossing the Sierra Shoshonee—Stinkingwater Pass—Yellowstone Lake—Great Falls on Grand Cañon—Explanation of origin—Hot Springs on Orange Creek—Great Hot Springs on Gardiner's River—Description and explanation—Fossil gas-bubbles—Amethyst Mountain—Fossil trees with hollows containing crystals of amethyst—Geyser basins—Yellowstone Lake—"Our Twenty-eighth Hop"—Ascent of Mount Sheridan—A deserted camp—Trouble with Indian scouts—Upper Yellowstone River—Discovery of "Two-Ocean Water"—The Three Tetons—Discovery of Togwotee Pass—Teton Basin—Head of Wind River—Return to Camp Brown.

[Special Orders No. 80.—Extract.]

HEADQUARTERS DEPARTMENT OF THE PLATTE,
***Omaha, Neb., May* 15, 1873.**

4. Capt. William A. Jones, Corps of Engineers, will proceed as soon as practicable to Northwestern Wyoming, and there make a reconnaissance of the country within the territory about the headwaters of the Snake, Green, Big Horn, Grey Bull, Clark's Fork, and Yellowstone Rivers. He will organize and equip his party at Fort Bridger.

Second Lieut. S. E. Blunt, Thirteenth Infantry, will accompany Captain Jones as assistant.

Assistant Surgeon C. L. Heizmann, United States Army, will report to Captain Jones for duty with the expedition, and to the commanding officer of the escort as medical officer for the troops.

The acting assistant quartermaster and *assistant* commissary of subsistence appointed by the commanding officer of the escort for his troops will perform the duties of *assistant* quartermaster and *assistant* commissary of subsistence for the expedition.

5. Company I, Second Cavalry, (*Noyes's,*) is detailed as escort for the reconnaissance of Northwestern Wyoming by Captain Jones, Corps of Engineers. The company will proceed by rail on the 4th proximo to join Captain Jones's party at Fort Bridger.

The Quartermaster's Department will furnish the necessary transportation.

* * * * * * * *

8. Second Lieut. R. H. Young, Fourth Infantry, will report in person to Capt. H. E Noyes, Second Cavalry, for temporary duty with his company.

* * * * * * * *

By command of Brigadier-General Ord.

GEO. D. RUGGLES,
Assistant Adjutant-General.

In compliance with the above order I organized an expedition in Omaha, Nebr., consisting of the following persons, viz: Professor T. B. Comstock, geologist; Dr. C. C. Parry, clerk, botanist, and meteorologist; Assistant Surgeon C. L. Heizmann, U. S. A., chemist; Second Lieut. S. E. Blunt, Thirteenth Regiment of Infantry, astronomer; Second Lieut. R. H. Young, Fourth Regiment of Infantry, acting assistant quartermaster and *assistant* commissary of subsistence; four topographers, one astronomical assistant, one meteorological assistant, three general assistants, one chief packer, two guides, and two laborers.

The party was concentrated and went into camp at Fort Bridger, Wyoming, June 5, the escort joining the same date. The officers on duty with the latter were Capt. H. E. Noyes, Lieutenants C. T. Hall, F. W. Kingsbury, and R. H. Young.

The sum of $8,000 had previously been allotted to me from the appropriation for "surveys for military defenses," for the purpose of making the reconnaissance, and proved sufficient.

The transportation, as furnished by the Quartermaster's Department, consisted of eight wagons and sixty-six pack and saddle mules, in charge of one pack-master and ten packers; also three six-mule teams and wagons were turned over to me for transfer to Camp Stambaugh.

Until June 12, the time was occupied in equipping the party, making final preparations for the march, and completing the preparatory work of the several field-parties. From Colonel Flint, the commanding officer of the post, I received the most cordial and hearty assistance, which contributed not a little toward our success.

An expedition for an ascent of the Uintah Mountains, at the head of Henry's Fork, was sent out, but on account of the great quantity of snow and the limited time at their disposal, was obliged to return unsuccessful. On the 6th of June the water rose so high in Black's Fork as to force us to abandon our first camp and seek a drier one.

Thursday, June 12.—The expedition broke camp at 8 a. m. and took up its line of march, moving northeasterly to the Big Muddy River, a distance of eighteen miles.

On the march the party was organized as follows: geologist, with one assistant; meteorologist, with two assistants; astronomer, with one assistant; medical officer, with a complete outfit for the analysis, in the field, of mineral and thermal waters and gases; chief topographer, with two parties of two each, one on the general triangulation and the other in charge of the odometer measurements and general description of the line of march. The odometers (three) were carried on a wheel attached to a pair of shafts, arranged for facility in moving over bad trails through timber.

The train, consisting of eleven wagons with the packers as teamsters, was in charge of Lieut. R. H. Young, acting assistant quartermaster for the expedition. These wagons carried a four months' supply of provisions, a complete outfit for a pack-train, and ten days' half-forage, besides the usual stores and camp-equipage. All supplies and train-material were concentrated at Fort Bridger in preference to the Wind River posts, because of the greater certainty with which it could be done in a limited space of time.

The triangulation was carried on with a small transit-theodolite, starting from points established by me in 1871, and using the prominent landmarks along the route as signals. The system worked well, the topographers having no difficulty in keeping up with the column in any march it could make. The odometers did not work well, three of them on the same wheel failing to record a like number of revolutions or even any approach to it.

The unusually high water in Black's Fork had seriously undermined the abutments of the bridge north of the post, but fortunately nine of the wagons crossed it with safety. The tenth broke through, but was quickly rescued, and the hole repaired, valuable and timely assistance being rendered by Captain Noyes and his command.

The line of march lay across the country known as Colorado Desert, flanking the southeastern extremity of the Wind River Mountains, and thence following up the Wind River Valley to Camp Brown. As far as these mountains the region is almost rainless, but the extraordinary spring rains had extended over it and fallen as snow in the surrounding mountains in enormous quantities. As a consequence, the streams were swollen to a remarkable extent, and rendered well-nigh impassable.

At this camp there is no wood, but little grass, and the water was excessively muddy.

Friday, June 13.—Broke camp early and commenced the passage of the Big Muddy. This was attended with great difficulty, as the stream, barely fordable, was running very swiftly, and the bottom was soft. The first wagon mired in the rapid current, and the mules were rescued with much difficulty, great skill and energy being displayed by the men in charge. After this accident a line was led from each wagon to the opposite bank and manned by Captain Noyes's men, and only the best teams hitched to them. The passage, though tedious, was effected successfully, and a march of 13.2 miles made to Ham's Fork by 3.30 p. m. Here the water was so high that the valley was largely overflowed and the ford absolutely impassable. Fortunately an old abandoned bridge, with its middle piers washed away, was found across the main channel, and this was successfully used in making a passage. The teams were unhitched and the wagons lightened to 1,000 pounds, and a detachment from the escort was then stationed on the opposite side, who drew them over the shaky bridge with great caution by means of a line. The unloaded material was then carried over by these men, and the teams led over with extreme care. There remained about one-fourth of a mile of low bottom, of alkaline soil, which was considerably overflowed and cut up with sloughs, over which the greatest difficulty was experienced. Work continued until nightfall, which found six wagons with their cargoes safely across, while the remainder were mired in the bottom, which was strewn with material unloaded from them.

Good grass and wood at this camp.

Saturday, June 14.—Commencing early, the passage was completed by 1 p. m., but the men and animals had worked so hard that it was not deemed advisable to make any march, and we went into camp. I consider this passage quite a feat, the success of which was very largely due to the conception and energy of Captain Noyes and to the untiring efforts of Mr. Curtis, wagon-master.

During the night some horse-thieves, who had been prowling around us, succeeded in getting two horses belonging to the escort. A party was sent out but failed to find them. Before leaving, however, the services of a citizen of Granger were secured to capture them if possible.

Sunday, June 15.—Marched 18.9 miles to Green River, which was at flood-height. Excellent road and good camp.

Monday, June 16.—Moved 3.3 miles down the river to the stage-ferry, by means of which we effected a crossing by 1 p. m., and went into camp. Green River flows through a narrow flat valley which is covered with sage-brush interspersed with good meadow near the water and on the islands in the stream. Groves of the inevitable cotton-wood are numerous. The stream is here of considerable size at any season of the year, but generally is fordable at a few places. Good camp.

Tuesday, June 17.—Moved 12.4 miles to the Big Sandy and commenced crossing it at 11 a. m. This stream was at flood-height, and the ford difficult from moving sands in deep water. The wagons were unloaded and reloaded after their beds had been lined with tarpaulins and tent-canvas. Teams of eight and ten mules were then hitched on, and they were carefully drawn through the swift current, the water coming up above the middle of their beds. The passage was effected by 2 p. m., and we went into camp. One mule was drowned. The two stolen horses were brought in this afternoon, having been recaptured near Black's Fork. The country passed through is a flat plain marked by a few buttes and benches; soil dry and sandy in many places, and the whole covered with a thick growth of sage-brush.

Big Sandy River is a stream having its source in the Wind River Mountains, and runs through a narrow sandy valley with but little grass and no trees.

This camp is at a stage-station on the route from Bryan to South Pass City and the Sweetwater mines. A little grass and no wood.

Wednesday, June 18.—Moved 17.1 miles to the second crossing of the Big Sandy. The ford was much more difficult than that at the first crossing on account of holes and quicksands. The channel was very much wider, though the water was hardly so deep. Twelve mules were hitched to one wagon, and hauled it safely across; but as this exposed too many mules to the danger of getting tangled in the harness and drowned in the rapid current, a line was led across to the opposite side, to which a ten-mule team was hitched, besides being manned by all of the men of Captain Noyes's command. By this means the wagons were pulled across, but not without much difficulty and very hard labor. One wagon was overturned in the stream, but its contents, except a few insignificant articles, were saved by prompt and skillful action. Fortunately they were not of such a nature as to be damaged seriously by being wet for a short time. One mule became entangled in the harness amid-stream and was drowned.

The ford was reached 12 m., and the crossing completed by 4 p. m., when we went into camp.

This is an eating-station on the stage-route. Water and grass; no wood.

Thursday, June 19.—Marched ten miles to the Little Sandy, where the crossing was made by 12 m., and camp was made. There is plenty of grass here, but no wood. The country traversed in the past two days is a hot, sandy plain, supporting a thick growth of sage-brush and grease-wood, and swept by strong winds from the southwest daily after about 10 a. m., during the hot season.

Commenced immediately laying out a secondary base-line. This work was finished by noon of—

Friday, June 20, when we broke camp and marched 13.8 miles to the Dry Sandy. Gnats were extremely troublesome at this camp, where there is but little grass, and no wood. It is a stage-station. The Dry Sandy is an insignificant stream which goes dry except at the stage-station, where there is a spring. The country traversed has the same characteristics as that passed through on the previous days.

Saturday, June 21.—Broke camp at 5.30 a. m., in the midst of a driving storm of cold rain, which soon turned into snow, and marched 10.6 miles to the stage-station at Pacific Springs. Here the storm turned into a severe gale of cold wind. Wood, grass, and water at this camp, which is on the northern border of the hot sage-brush plain over which we have been traveling. This vicinity is the "South Pass" of the early geographers, about which there has been so much fictitious writing and picture-making. As there are no mountains about it, and as the old road hardly crosses a hill of any magnitude, the misnomer is evident. The road, however, crosses at this point the divide between the Atlantic and the Pacific flowing waters, and this gave origin to the name.

Captain Noyes, Lieutenant Hall, and a small escort went ahead to Camp Stambaugh.

At this point I received a communication from the commanding officer of Camp Stambaugh, informing me of the presence of hostile Indians in his neighborhood. Rumors had already reached us of their depredations, and I had already commenced precautionary measures by keeping my guides in the morning and evening on the lookout for signs.

Sunday, June 22.—The night was very cold, the minimum thermometer registering 21° F. Broke camp at 1 p. m. and marched four to six miles to the Sweetwater River, crossing over a bridge that is used in high-water seasons. The stream is generally fordable. Evidences of a recent and considerable fall in the water were abundant. The river here runs through a narrow, flat-bottomed valley, with sharp rugged sides of metamorphic rock. The soil is rich in garnets of small size, with slight indications of gold. The road traversed thus far from Fort Bridger has been excellent.

Monday, June 23.—Broke camp at 6.30 a. m., and marched sixteen miles to Camp Stambaugh.

The route passes through the mining-towns of South Pass City and Atlantic City, and traverses the greater portion of the Sweetwater gold-mining region across the slopes of the southeastern extremity of the Wind River Mountains. These mines are in a belt of metamorphic schistose rocks that occupies the axial line of the mountains. They are very favorably located for working, and good roads are within easy reach, although water is so scarce that placer-mining does not prosper as it certainly otherwise would. On Strawberry Creek, near Camp Stambaugh, it was found remunerative to haul the dirt several miles to water. The gold occurs singularly free in veins of a bluish, impure quartz, generally rather thin. For some reason, or reasons, this industry is in a languishing condition. This was partly caused by a great silver excitement in Utah, which drew away a large portion of the miners to that ever-fascinating new country that they do not happen to be occupying. There is every indication here of gold in paying quantities, but a stage has been reached where capital is needed for further development.

Camp Stambaugh is situated on the southeastern extremity of the Wind River range, where it has run out to an elevation of about 8,000 feet above the level of the sea, and is exactly on the divide. Thus elevated in position, it lies between and commands the two lines of approach and escape over which the marauding parties of Sioux, Arapahoes, and Cheyennes, from about Fort Laramie and Fetterman, make their almost regular annual descents upon the Wind River and Sweetwater settlements and stage-stations, lying respectively to the north and south of it. These two lines are connected by difficult trails over the high foot-hills of the range, above and to the northwest of Camp Stambaugh and the exposed mining settlement, so that either can be chosen as a line of escape after an outrage.

The obvious mode of getting at these Indians, after their presence has been made known in the usual manner by some depredations, is to move the troops with the utmost celerity to some point near the junction or convergence of these lines, which probably would not be more than one hundred miles to the east or north of east from Camp Stambaugh, and there throw out an efficient line of signal-pickets. By this means, if they did not reach their objective point in advance of the escaping Indians, they would not be unlikely to stumble over them on the way.

Indians travel over a country guiding themselves by the prominent or noticeable landmarks, and when these are not sufficient, they build piles of stones on a hill or in a doubtful pass. As a consequence, their trails of general travel must almost of necessity converge or diverge at or near some of these points, and however much a party may scatter, it will come together again in the vicinity of some such place. These are really strategic points in Indian warfare, because the most difficult part of the matter is to get at the Indian, and he can best be reached through a thorough knowledge of his modes of travel.

About Camp Stambaugh and the Sweetwater mines the grazing is generally good, but the country is nearly barren of timber, which, however, is abundant higher up in the mountains. The climate is very severe, and strong winds are almost constantly prevalent.

Until June 28 the time was occupied in shoeing animals, repairs, &c., and as many as possible of the mines were examined by Professor Comstock and myself. Both of the box-chronometers, which had been carried by a mounted man in a basket attached to a sling, had been so erratic in their rates that they were left behind here, and the remainder of our work was done with pocket-chronometers. Three wagons and teams which we had brought from Fort Bridger were turned in.

We were received at this post with the utmost courtesy and attention, and the commanding officer, Lieutenant-Colonel Brackett, cheerfully accorded us every assistance in his power.

Friday, June 27.—Starting at 6 a. m., we marched 8.2 miles to Twin Creek. The road passed through Miner's Delight, the most thriving of the mining towns in this locality, was very hilly, and in some places quite boggy from the late-melting snows. The long slopes of the foot-hills of the mountains are here covered with a splendid growth of grass, and there is a scattering growth of timber, pine, spruce, and aspen. It is a region admirably adapted for grazing.

Saturday, June 28.—Broke camp and marched 12.2 miles to Murphy's ranche, on the Little Popo-Agie River, which latter had very recently fallen so as to just permit us to ford it. There is here a small but well-sheltered valley of rich soil, where vegetables and hardy cereals are successfully cultivated.

Sunday, June 29.—At 6 a. m. we broke camp and marched 15.5 miles to the North Fork of the Big Popo-Agie River, crossing the valley of the principal stream on the route. This latter is of considerable size, has a rich soil, lies well for irrigation, and is well watered. The climate is quite mild. It is the old site of Camp Brown, and is now occupied by a small settlement of whites, among them several women.*

The valley of the North Fork is quite similar, although the land does not lie so well for irrigation. The grazing-land everywhere around is very fine.

Monday, June 30.—Marched eleven miles to Camp Brown. The road from the crossing to the Little Popo-Agie follows a monoclinal valley parallel to the mountains, and is excellent. The country is rolling, with a good soil, supporting a fine growth of grass, but no trees. Camp Brown is situated on the right bank of Little Wind River, just above the mouth of its north fork. The stream has just emerged through a short cañon from the long rolling outlines of the mountains, and shows a broad, flat, and well-watered valley of rich soil. A large area of land in this valley can be irrigated with but little expense. The climate is very mild and, so far as observation has yet gone, but little snow falls during winter. The mild and dry climate is easily accounted for from

*Shortly afterward hostile Indians made a descent upon this settlement and butchered two of these women. They also attacked Murphy's ranche, but were driven off.

its situation under the lee of a very high range of mountains, which catches the prevailing storms on its southern face and deflects them to the south, whence they are drawn down the Sweetwater Valley as through a funnel, making a fierce eddy and the corresponding severe climate over South Pass City and Camp Stambaugh.

On the river, two miles below the post, there is a large, hot sulphur spring in a small lake, which has remarkable properties for bathing. An analysis of the water, by Dr. Heizmann, discovered chloride of lime as one of the constituents. The temperature is usually 110° F. Near by there is a running oil-spring, and also large beds of gypsum and alabaster. There is also a cold sulphur spring a few miles southwest from the post.

Near by is the agency of the Eastern bands of the Shoshonee Indians. Their chief, Washakee, is thoroughly well known on the plains, and is a man of considerable ability and foresight. He expressed a strong desire to see a railroad come through his country as a result of this expedition, and took great interest in it.

Table of distances.

	Miles.
Fort Bridger to Camp Stambaugh	135
Bryan, on the Union Pacific Railroad, to Camp Stambaugh	99.5
Bryan to South Pass City	93
Bryan to Camp Brown	146

Bryan is the point from which supplies are shipped to the Wind River posts.

Until July 10 we were engaged in turning in the wagons and wagon-train material, rigging up the pack-train, and in measuring out a base-line and carefully locating the principal landmarks with a large transit-theodolite. An expedition for the ascent of the Wind River Mountains went out on the 5th and returned on the 10th. Ten Shoshone Indians were enlisted as scouts, and Narkok, a petty chief, was employed as guide. These Indians stipulated that their families should be permitted to accompany them. To this I had no objection, as it insured their good behavior, and they could easily travel as fast as we would be likely to.

We received the utmost courtesy and attention from the officers at the post, and the most cordial assistance from the commanding officer, Captain Torrey, and Lieutenant Guthrie, post quartermaster. On the 10th of July we broke camp early and attempted to make a march, but many, in fact most, of the train-mules were entirely new to packing, and created such havoc, that we were quite content to move one half of a mile across the river and go into camp again. It took all day to accomplish even this much, and there was great amusement and excitement over the desperate struggles of the frightened and frenzied mules. Mules require a season of training before packs should be put on them for a march, but this we had no time for, and were obliged to break them in while on the march. This involved the breaking of nearly every breakable article in our outfit, and many a sigh was mingled with the laughter over the antics of some wild mule as one after another of the fragile luxuries of camp-life disappeared from usefulness.

Friday, July 11.—The morning was spent in repairing the damages of yesterday's attempt at a march. Made a start at 2.30 p. m. and marched 8.4 miles to Sage Creek. This small stream has a bottom of soft mud and runs between almost vertical banks of alluvium. Our camp was at the nearest point to Camp Brown where it is fordable. There is no ford below it. Poor camp. There is a little grass, no wood, and poor water.

Saturday, July 12.—Marched 10.7 miles to Wind River. Passed over a high plateau covered with sage-brush, from which there is a considerable descent to the valley of the river. This was swollen to a great height and was not considered fordable. We were prepared to make a raft-ferry over it, but I thought it advisable while looking for a suitable spot to also see if a ford could be possibly found.

Sunday, July 13.—This morning the Indians set at work with the utmost spirit in search of a ford. They stripped off all clothing except the soldier's blouse, with which they had been furnished, and, mounting bare-back, drove their ponies into the stream at every possible point, where they soon became involved in many dangerous as well as ludicrous situations. Three or four hours of this sort of work was followed by the announcement that they had found a possible ford. The line wound around and up and down among the islands and shoals in the channel in the most tortuous manner, and displayed an intuitive knowledge of the effects of flowing water that was remarkable. It was really a skillful feat. Great care had to be observed in this crossing, as the line frequently ran along narrow shoals amidstream, where the rapid current was more than swimming-deep a few steps on either side. Six hours were occupied in effecting it, when we went into camp on the opposite side.

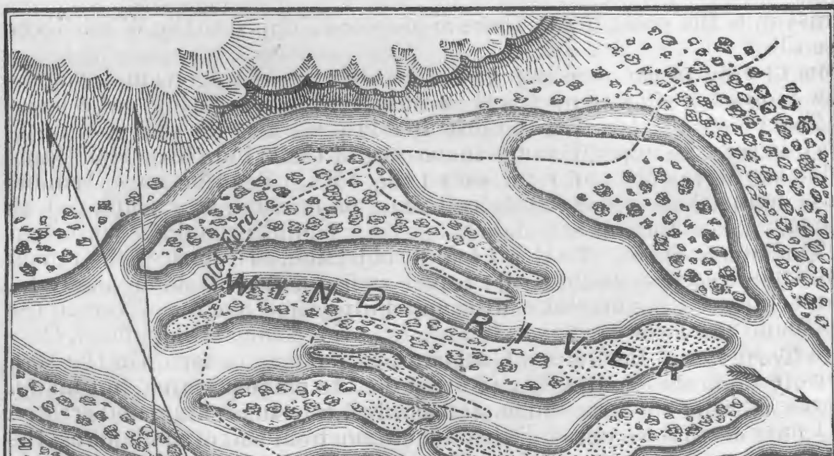


Fig. 1. Wind River Ford. (Shown by broken line.)

A fine specimen of gold quartz (*float*) was found near this camp, washed down probably from near the summit of the Wind River range.

Crossing the river afforded a rare spectacle; for a while, the long, tortuous ford was completely lined with the motley crowd of soldiers, citizens, pack-mules, and gaudily-dressed Indians, with their squaws, children, and numerous loose ponies. Among them was a colt which, on account of the deep water, was strapped legs up, to the pack carried by its mother. The presence of these Indians, who formed a small

ERRATA.

The following paragraph should follow immediately after Figure 1, page 12:

In the vicinity of this crossing, Wind River flows through a broad riband of meadow, of varying width, with numerous groves of cottonwood, which grows to quite a large size. The approach by the right is over very high terraces of soft earth. These plateaux are so high that their cultivation by irrigation is probably out of the question. The soil is rich, and is covered with sage-brush and the characteristic bunch-grass, which latter is of quite superior size. Wild licorice occurs in the valley. On the left bank these terraced deposits are mostly worn away, leaving many buttes and benches, among them Crow Heart Butte, whose height and characteristic features render it a very noted landmark in the valley.

village, gave us a rare opportunity of studying their habits and mode of life. They proved to be extremely vigilant, and their conduct was unexceptionable.

Monday, July 14.—Marched 14.8 miles up Dry Creek, on which we made our camp. The country rapidly grows coarse, dry, barren, and very dusty. No water, except in the creek, where it is poor; wood and grass are scarce.

Tuesday, July 15.—A topographical party which had been sent to a station in the Wind River Mountains overtook camp at 10 a. m., when we took up the march and moved 10.3 miles along the same creek, going into camp at a spot where there was plenty of wood, tolerable grass, and poor water. Dry Creek, from its name, probably does not always carry water through the season.

Wednesday, July 16.—Broke camp 9 a. m., and marched 18.5 miles through the foot-hills of the Owl Creek Mountains. The line of march lay through a country extremely desolate and quite mountainous in its character, the rocks being frequently tilted vertically, with some very large dikes of quartzite. Some quite extensive beds of gypsum and alabaster occur, with deposits of iron-ore, (brown hematite.) These give to one cañon on the route a highly variegated appearance, which led us to call it "Painted-Rock Cañon." Along the route, water, wood, and grass are very scarce, and only one stream (the Little Muddy) was crossed. It was almost dry thus early in the season. At camp the water was from springs that were nearly dry, and was quite alkaline; and the grass was thin and poor. There is no wood. In this region the rocks are tilted and flexed in quite a remarkable manner, apparently by forces from two directions, making a considerable angle with each other. I saw indications of coal, but may be mistaken.

Thursday, July 17.—Broke camp at 9.30 a. m., and marched across the Owl Creek Mountains, camping on the Middle Fork of Owl Creek. Distance 10.5 miles, over an easy trail. Wagons from Camp Brown have been taken across at this point and as far north as the Grey Bull River.

The mountain-slopes are generally rounded, and covered with a fine growth of grass; timber, aspen, pine, spruce, and hemlock, occurs in extensive groves, and there are many springs and small streams on the northern water-shed.

At 5.30 a. m. I took a small topographical party, with an escort and some Indian scouts, and started to make the ascent of the peak which forms the climax of the range, and reached the summit by 9 a. m.

I have named this peak Phlox Mountain, from the extensive fields of white phlox that its slopes display. From this point it was seen that we were entering the Big Horn Valley close under the eastern flank of an enormous range of mountains whose existence, although suspected, was unknown. Subsequent observations showed it to be the same as that bordering Yellowstone Lake on the east, and connected with it by a belt of massive peaks fully sixty miles in width. To the north and east lay the Big Horn Valley, visible through nearly its whole extent, with its streams running transversely from the unknown range to our left into the Big Horn River northward. As far as the eye could reach could be seen a grand and endless series of faces of broken strata of the sedimentary rocks looking up to and dipping away from the Owl Creek range. Strangely enough no strata could be seen dipping from the vastly larger range on our left. Toward the southeast the Owl Creek range evidently ran out in the vicinity of their crossing of the Big Horn River; to the northeast were the Big Horn Mountains, of which little could be seen except Cloud Peak and a few peaks in its vicinity, distant one hundred miles. Subsequent and frequent examinations of this range from a distance of eighty miles, and from many high points, show that, with the exception of the cluster of culminating points just mentioned, the range must be a low one, with the general line of the summit much below the timber-line. North of Cloud Peak this summit appears remarkably even and free from peaks, from which I infer that it is a high, rugged plateau. Very little water drains from their western slopes, and the country appears quite desolate and barren. To the southeast lay the "bad lands" that are inclosed within the angle of the "big bend" of Wind River, coming quite up to the foot of the Owl Creek range. The quantity of water that drains from the south slopes of this range is quite small, and from the north slopes but little is supplied to Owl Creek, which is in reality a drain from the mountains to the westward; to the south, across the valley, the Wind River Mountains stand out in massive grandeur, with snow-clad peaks along their whole length. From the Indians I learned that the snow disappears during the summer from all except in the vicinity of Union Peak. Along their flank, and sweeping up to their summit from the valley below with wonderful symmetry and regularity, lay the huge layers of Silurian, Carboniferous, Triassic, Jurassic, Cretaceous, and Tertiary rocks, forming immense ridges, and forcing one to the simile of the petrified waves of a mighty geological ocean.

I noticed in this vicinity that along the summit, in the neighborhood of Phlox Mountain, the metamorphic rocks are similar and are arranged similarly to those at the summit of the Wind River range. Good camp.

Friday, July 18.—Left camp at 6 a. m., with a topographical party, accompanied by Professor Comstock and Lieutenant Blunt, to make the ascent of what appeared to be the highest peak in the range west of us, distant about fourteen miles. The approach appeared to be one of great difficulty, and when I asked the Indians if they could guide me to a point somewhere near it, they said they knew of no way to get there at all. I had examined the country for an approach the day before from Phlox Mountain, and could see none except by following along the south slopes of the Owl Creek range. This varied considerably from a direct line, but seemed to be free from cañons. The question was a serious one, as the peak was so far away, and evidently of such a difficult character, that a mistake would be attended with a considerable loss of time. At 12 m., after a rapid march of six hours, I ascended one of the peaks in the Owl Creek range to reconnoiter for a further approach, and was fortunate in picking out one by which we could probably reach the foot of the peak by night-fall. In a short time we reached Owl Creek, just above its grand cañon along the anticlinal axis of the mountains, and at 6 p. m., thinking ourselves near enough for the assault to-morrow, we made our bivouac, after a pretty hard day's work.

Saturday, July 19.—Taking an early start, we commenced examining the peak for a feasible point of attack, and marched up Owl Creek until 9 a. m. before finding one. We then secured our animals, and at 9.30 a. m. the ascent was commenced.

This peak, to which I have given the name of the "Washakee Needles," is a terrible crag. Its appearance from the valley of Owl Creek, above our camp, is simply frightful, sheer precipices of whitish lamellar granite rising up from the valley fully 2,500 feet high. From this side it is unassailable, and we spent the best part of the morning in looking for a way across to the other side, expecting to find there a slope of some kind. After five hours of severe and extremely dangerous climbing, three of the party—two of the topographers, very fortunately, and to my astonishment, with the barometer and theodolite—and myself found ourselves at the limit of progress toward the summit. The peak is formed by several huge plates of granite, whose summit-lines are serrated with teeth at which the edges are generally vertical. The summits are so narrow that in places one can actually sit astride, with legs dangling over great precipices on either side. We were upon the serrated summit of the plate adjacent to the highest one, whose summit loomed with precipitous sides fully 200 feet above us. Between was an immense gulf separating the plates. Not only was further progress impossible, but we could see now that the summit was absolutely inaccessible except with the aid of appliances for climbing, and probably not even with them. We took the angle and estimated the distance to the summit; finished our instrumental work upon a ledge a little below our highest point, for there was not room on top to set up an instrument and use it, and were very glad, indeed, to commence the descent. The situation upon our perch—no one dared stand up on it—was anything but pleasant, and we left it only with the burning regret that it had not been the summit. Messrs. Putnam and Bond, who carried the instruments up, certainly deserved success. The approximate altitude of the peak is 12,250 feet. From our dangerous perch the view, spread out to the north and west, was grand and even terrible. As far as could be seen lay a jagged mass of peaks of dark-brown volcanic *ejectamenta*, which showed black in the shadows of the falling sun, giving to the whole that appearance of black shadow and mystery which always produces such strong impressions on the mind.

Later observations lead me to the belief that we were looking upon the headwaters of the Snake and, possibly, the Yellowstone Rivers. We were upon the highest peak in sight in this range.

By 5 p. m. we had completed the descent, and found the rest of the party, one of whom, Lieutenant Blunt, had narrowly escaped with his life.

We marched back over our trail until after dark, and then made our weary bivouac for the night.

Owl Creek, above its cañon, runs through a splendid park, abounding in game—mountain sheep, bear, elk, deer, and buffalo.

Sunday, July 20.—Started back a. m. for camp over a route selected from the mountain yesterday, and reached it 1.30 p. m.

Monday, July 21.—Marched north-northwest eighteen miles to Cottonwood Creek. The line of march lay through the grassy and well-watered foot-hills of the mountains. Scrub-cedar grows upon the hills, and cotton-wood along the streams, both somewhat sparsely. This country is a favorite range for buffalo. The grass is very fine. At camp we found a very cold spring, temperature 41° F. Wood is scarce, and there is an outcrop of coal near by. I have renamed this stream Mee-yer-o Creek, giving it an Indian name. The early trappers, following the Indian practice of referring to streams by means of the natural features about them, have inflicted the country with numberless Cotton-Wood, Willow, Sage, &c., Creeks, which is sure to lead to much confusion hereafter. From what I could gather, I am of the opinion that the Shoshonees do not have distinct names for the streams and mountains, but refer them, where they are not in sight, to prominent landmarks or characteristic natural features in their immediate vicinity; thus, the Stinking Water River would be spoken of as "the stink water in such a direction and near such a landmark;" the South Fork of the Stinking

Water, as "the water with a peculiar-shaped rock close by it;" Beaver Creek, as "the little water near such a landmark, where there are many beavers;" Wind River, as "the big water by such a landmark, where the wind blows very hard," &c. I do not think that they have names for the mountain-ranges at all. As there is a remarkable sameness among the natural features along the streams in the plateaus of the Rocky Mountains, it results that a large number of streams are named alike. On this account I have changed a few names.

Tuesday, July 22.—Marched 13.6 miles to Beaver Creek, and went into camp 12.30 p. m., where we found good grass, wood, and water. The country is still high-rolling, with fine grass all over it, and few trees. Extensive patches of the wild gooseberry grow along this stream. I have renamed it Gooseberry Creek, feeling little apprehension that the name will be duplicated.

Wednesday, July 23.—I find that by making marches in the forenoon everybody becomes too tired to work to advantage in the afternoon, and have therefore decided to make them in the afternoon, starting about noon. Were we simply marching through the country it would be different, but in cases of this kind the marching should be made subsidiary to the work of examining and describing the country. As our marches are short, it is not too fatiguing to travel in the heat of the day, and we are thus enabled to examine the country about camp during the forenoon, obviously to greater advantage. Another advantage is that the animals have plenty of time to graze before starting on the march, which they do not have when an early start is made, and it is very important that pack-animals should eat their fill before starting on a march.

Some Shoshonee Indians came in from Washakee's camp near the Stinking Water River. They report immense herds of buffalo lower down in the valley, and that the village is having a grand hunt. We have seen a number of straggling buffalo in the past few days, and several have been killed.

Marched 10.7 miles to Grey Bull River. This is a stream of considerable size, running through a narrow valley, which two or three miles above widens out very much and encroaches into the mountains. An expedition of miners, called the "Big Horn Expedition," came into this country from the South in 1870, and brought one wagon as far as this stream. Here they disbanded and the most of them returned to the settlements *via* Camp Brown, while a few made their way into Montana by the way of Clark's Fork and Rosebud.

Thursday, July 24.—Marched seventeen miles to a small tributary of the Stinking Water, which I have named Mee-tee-tsee Creek—a Shoshonee name. Grass and water are a little scarce. About three miles ahead of us, at the foot of a huge spur from the mountains, the Shoshonee village is encamped. The divide between the Grey Bull and the Stinking Water is quite high, and the descent into the valley of the latter rather abrupt.

We have had all day a good view of the Big Horn Mountains, and I am satisfied that, with the exception of Cloud Peak and a few peaks about it, the range is comparatively a low one. The valley of the Big Horn appears very desolate, except along the valleys of the streams, which are fringed, as usual, with cotton-woods and narrow, grassy bottoms.

Friday, July 25.—This morning Washakee, with a large party of his braves, in full dress, made me a state call. He was much interested in the expedition, but did not seem so well pleased at having so many of his best young men go with us as soldiers.

At 2 p. m. we moved camp 4.4 miles, to a point near the Shoshonee village. Five more of them were enlisted by Captain Noyes, and one joined us as a volunteer, raising the number of Indians with our party to seventeen. The captain also swapped off a poor unfortunate fellow who had developed a case of hopeless sore eyes for a healthy one. The tribe is terribly afflicted with syphilitic affections. The village was perched well up on the mountain-side, on a small stream which here opens out into a diminutive valley, just above a long, gloomy cañon. Its existence would never be suspected from below. From the lookouts the view of their sentinels swept all possible approaches thoroughly. Unobserved approach was impossible, and a better place for defense could not well be selected. Constant incursions into this valley of large war-parties of Sioux gave wisdom to their precautions.

To our surprise, the mountain-spur above us is composed almost, if not entirely, of volcanic matter, which, in some places, contains fossil trees of considerable size. Its measured altitude is 8,607 feet, which is 3,400 above the valley of the Stinking Water. Grass is thin and wood scarce.

Saturday, July 26.—Marched 18.8 miles to the North Fork of the Stinking Water River, crossing the South Fork, or Ish-a-woo-a River. I have given this stream the Indian name of a peculiar-shaped rock, by means of which they distinguish it. It is a remarkable, finger-shaped column of volcanic rock, standing alone in the valley, about three miles above our crossing. The valley of the Stinking Water has here an elevation of 5,273 feet above the sea, and is the lowest point touched by the expedition. Just below the junction of the two forks, and about a mile below our crossing, the river, by a deep and rugged but short cañon, cuts off the point of a sharp and high anticlinal ridge of yellow limestone which stands vertical along the summit, leaving a high, bold peak on the right bank, which the Indians use as a landmark. They refer to it as the "mountain with many cedars." I have, therefore, called it Cedar Mountain. High up on its southern face is a remarkable hole, which the Indians called my attention to, and said it was very deep. I could, with my glass, see that it was a hole, and intended to visit it after reaching camp, but was prevented from doing so by more urgent business. About twenty miles northeast from this point is a small, isolated cluster, which is probably the Heart Mountain of the early trappers and guides.

To-day we began meeting with huge spurs running out from the mountains at about right angles; also evidences of tremendous volcanic action. The drift in the valley is composed of the *débris* of volcanic rock. We passed the remains of a large depositing-sulphur spring. The water oozed from a cylindrical mound of soft mud, a little hardened on its rim and held together by the roots of a rank growth of water-grasses. It lies close to the Ish-a-woo-a River, on the south side near where our trail crosses, and probably at one time contributed largely to the odorific title of the main river. A few miles lower down, below the cañon, a mass of sulphur springs occur which still give good cause for the river's name. On the North Fork we found the extinct remains of a mass of depositing springs; the whole hill-side was covered with the large sedimentary mounds of soft black and brown earths, having a good deal of transparent gypsum in crystals and small pieces scattered through them.

On the mountains there is a tolerably heavy growth of coniferous trees, and along the streams the everlasting cottonwood flourishes. The valley of the North Fork for a considerable distance above the cañon has very little grass except a very tall, coarse kind, that grows in patches near the water, and is not sufficiently nutritious to induce the animals to eat it. The soil has a peculiar greasy, yellowish look, and only supports a stinted growth of grease-wood and sage-brush. The Stinking Water is a river of considerable size, and, probably, is rarely fordable below the junction of its two main forks. We had considerable difficulty in finding a ford across the Ish-a-woo-a, even this late in the season, and probably neither of the forks are fordable much earlier.

Above the cañon the waters of both streams are perfectly pure and have no smell. Fine trout are abundant and game has been very plentiful. The tracks indicated that the elk and mountain-sheep have lately moved higher up into the mountains.

Sunday, July 27.—Marched 14.7 miles up the North Fork of the Stinking Water, and camped at the mouth of its grand cañon. We entered the mountains yesterday. Along the trail the soil is rather poor and the grass is thin. Wood is abundant. The latter part of the trail, for about six or eight miles, is quite rough, and crosses a small but remarkable bed of tertiary deposits of colored marls and clays.

The mountains are very rugged. The rocks are mainly limestone, sandstone, and a coarse volcanic conglomerate. The sedimentary rocks soon disappear, and the peaks are composed of, apparently, horizontal layers of volcanic ejectamenta. The prevailing color is a dark-reddish brown, which gives the mountains their marked black haze in shadow and bronze tint in the light. The conglomerate weathers into the most fantastic pinnacles, needles, and grotesque forms. When interstratified with the rich brown sandstones it weathers into characteristic rounded columns, displaying tier upon tier, reaching above the timber-line into the clouds, of sculptured balconies supported by long processions of pilasters and clustered columns, while, clambering up from below, forests of spruce and pine, growing on seemingly impossible slopes, cover the mountain-side to the upper limit of forest-growth. Compared with any mountain scenery that I have seen, the effect is quite peculiar, and even magnificent. The massive grandeur of the huge peaks is suffused with a rare beauty of form and color. At the mouth of the cañon, upon either side, stand two lofty and slender peaks of similar form, which I have named "The Sentinels."

Monday, July 28.—Marched up the stream 9.1 miles. The trail enters the cañon, and is very difficult, leading along steep and seemingly impossible slopes above the river, with frequent precipices below and above. To avoid a huge precipice which reached quite into the river, unfordable through the cañon, it made a detour to the right over the most difficult hill met with on the trip. It did not seem possible for animals to climb it, and the mishaps to the pack-train were quite numerous.

The grotesque forms of the conglomerate previously alluded to afforded great amusement to the party. It is really something remarkable.

After the hill came a short, broad bottom of sage-brush, and then the huge precipice-walls of the cañon closed in upon the river, leaving only a narrow bank, first on one side and then the other, densely covered with cottonwoods, brush-willows, and scattering pines. It was necessary to ford the river repeatedly—no easy matter—and the dense undergrowth of brush made progress anything but pleasant. Earlier in the season this stream is in all probability unfordable, and progress along our trail therefore impossible. At last we came to a patch of grassy bottom, just large enough for the party to camp upon, and a halt was cheerfully called.

The cañon-walls are streaked with dikes and veins. To-day and thenceforward it was found necessary to send a pioneer party from the escort ahead of the main body to clear and make the trail. Captain Noyes generally took charge of this party, and to his untiring efforts the expedition owes much of its successful progress.

During the day the Indians have been following the fresh trail of two white men with two led horses, who have ascended the valley just ahead of us. After reaching camp one was sent ahead to reconnoiter, and about three miles farther on he found them, just as they had predicted; two white men with two spare horses, which were packed. They were prospectors from Clark's Fork, and were greatly relieved when they found we were not Sioux, as they had supposed upon first sight of our Indian scout.

Tuesday, July 29.—Laid in camp. The pack-train was so badly used up that it was necessary to give the animals rest, and replace the lost shoes and tighten the loose ones.

Wednesday, July 30.—Broke camp and marched 14.5 miles up the stream. The trail was extremely difficult and beset with danger, both upon land and in the water. In one place it was so dangerous that even the Indians dismounted and led their ponies over it. Those who understand how Indians stick to their ponies in the most unheard-of places rather than dismount, will appreciate the difficulties of a situation that induced them to travel on foot. The stream was forded seven times. At one of these crossings, which was quite difficult, a pack-mule lost his footing and floated, pack and all, some distance down stream. Through the extraordinary exertions of Mr. Curtis, our chief packer, this animal was saved, though at the expense of its cargo and aparejo. Mr. Curtis came very near drowning, and broke one of the bones of his right hand—a serious accident.

On this march we emerged from the cañon and came into the park that is usually found near the head of mountain-streams. At camp there was splendid grass and plenty of wood. Along the stream is a thick growth of cottonwood, pines, cedar, and willow. The mountain-slopes are densely timbered.

We are passing through what appears to be one ridge of maximum elevation in the mountains. They seem to be composed entirely of material thrown from or poured out of volcanoes, and yet no distinct craters, or anything that looks like them, can be seen. Estimating from the timber-line, many of these peaks are over 12,000 feet high, and some carry at this season vast fields of snow on their northern slopes. From the precipitous character of the weathering about their summits, many of them will probably be found inaccessible.

Thursday, July 31.—The Indians say that I can make one "big march" to the divide, or two easy ones, and get across it. I choose the latter, and we start at 12.30 p. m., marching eleven miles up the river.

The trail leads through a perfectly lovely country of open pine forests, carpeted with long soft grass and the mountain-huckleberry. This berry is quite small and red, and has a very delicate flavor. We camped in a spot that was absolutely perfect, having ice-cold water, a broad meadow of thick grass, with dark forests of spruce and pine close around, carpeted with a long grass that makes our camp-bed feel like down. Elk, deer, and trout are abundant. A mule deer was killed.

I find to-day that we have crossed the highest ridge of the mountains and that the pass at the head of the Stinking Water is probably through a secondary ridge, and not the main divide.

At this point it became necessary to ascend a neighboring peak to do some important topographical work, and it was decided to lay over one day for the purpose. In this connection the question of provisions asserted its importance. It appeared that by making all possible haste to Yellowstone Lake, and sending the pack-train from there to Fort Ellis for supplies, the party left behind would be out of provisions before it could get back. As one day more or less in a case of that kind would not make much difference, it was decided to lie over, do the necessary work, and meet the consequences by shortening the allowance of provisions, should it become necessary. An examination showed that the soldiers had eaten more than their allowance of flour; that my party had consumed considerably more than its allowance of everything, and that the Indians had devoured their rations long ago and were subsisting on the country. They frankly confessed that the supplies thus obtained were rather scanty, and that they were getting hungry. Just here may be explained the secret of the tremendous marches made by war-parties of Indians. Having the power of going several days without food, they have no need of a train to incumber their progress.

Friday, August 1.—Started at 5.30 a. m. with a party consisting of Dr. Parry and Messrs. Bond and Putnam, with the theodolite and barometer, to make the ascent of the peak before mentioned, and reached the summit after three hours of pretty stiff and some dangerous climbing. The point proved a very good one for examining the eastern slope of the divide between the Big Horn and Yellowstone drainage. We were in the midst of a mass of wild and rugged peaks, seemingly thrown together in the direst confusion. To the west, and not far distant, was a line of peaks which evidently formed the "divide," and through a depression in it, to the northwest, we could see mountains, which were evidently upon the farther side of the Yellowstone Valley. The day was spent in work at the summit, and we reached camp at 7 p. m. very tired and hungry. This peak we have named "Sailor Mountain."

Saturday, August 2.—Broke camp at 8.30 a. m. and marched 14.4 miles, across the divide and into the Yellowstone basin, about one mile from the pass. The trail was excellent, except the short spurt of ascen into the pass, which was severe. This slope is on a friable volcanic sandstone, carrying but little soil, and smooth and bare in many places. The horse in the odometer-cart broke down completely at this spot, and the cart had to be left behind.

After the Indian guides, I was the first to reach the summit of the pass, and, before I knew it, had given vent to a screeching yell, which was taken up with a wild echo by the Indians; for there, seemingly at their feet, and several miles nearer than I had expected, was spread out a scene of exceeding beauty—Yellowstone Lake—embosomed in its surrounding plateau, and a mass of green forest extending as far as we could see. Slowly, and in single file, the remainder of the party came toiling and panting up, leading their animals, and, spite of lack of breath, each gave the same involuntary yell as the wonder-land burst upon their view. Perhaps there was something that moved us in the broad and startling contrast between the dreary deserts, the sage-brush plains, the awful and majestic mountains, and that broad expanse of fresh, hazy, and sensuous beauty that looked up so invitingly at us from below; but there was also the proud feeling that we had crossed the "impassable" mountains.

There was no time to be lost, however, and I ascended a neighboring peak in company with the theodolite-and-barometer observers, to do the important work that was now presented to us. From this point it could be seen that Yellowstone Lake lay in a broad and high rolling plateau, densely covered with trees; that from it, to the west and south, there are *no mountains* except Mount Sheridan and the Tetons, and that the country probably slopes off gradually in those directions into the basin of Snake River. We found fresh tracks of mountain sheep exceedingly numerous, but there was so much noise that they took the alarm in time to get out of sight. Two bears came down to witness our passage, but the hostile demonstrations of our Nimrods scared them away.

We reached the camp of the main party at sundown, when it appeared that Dr. Parry and the two white guides were missing.

I have named these mountains "The Sierra Shoshonee," because the right to name them is clearly mine, as I have been the first to cross them and mark out their geographical position and extent. Professor Hayden has called what he has seen of them and their western border sometimes the "Snowy Mountains" and sometimes the "Yellowstone Mountains," but he has also applied the latter name to a range lying south of Yellowstone Lake, that has no existence.*

Sunday, August 3.—Owing to a miserable *contretemps*, this day was lost. The trail to the lake was not found by 2 p. m., so I had the train unpacked, and went into camp without making any move. This camp was in a small opening in the forest, near a very large, gushing spring, whose temperature was 38° F. There are also, close by, some bubbling gas-springs from pools of water at 38° F., that have regular one-minute intervals between times of maximum action. The gas is sulphurous acid. Grass was very scarce and poor about camp. Measures were taken in the morning to discover our whereabouts to the supposed lost members of the party, and the odometer-cart was brought in. At 2.30 p. m. I took four packers and went back to the old trail, which we rapidly followed down to the prairie on Pelican Creek that was open to the lake. Returned to camp at 6.30 p. m., where I found a note from Captain Noyes, informing me that he had made his way to the lake, and that the three missing persons were there, and not likely to suffer, as they had killed an elk.

Monday, August 4.—Broke camp at 9 a. m., and marched about eighteen miles, to the outlet of the Yellowstone Lake. The last of the three odometers gave out to-day. About six miles from camp we came upon a lake of warm water, with a multitude of diminutive hot sulphur and gas springs on its eastern shore, and some large springs breaking out from beneath the water near this shore. It is the recipient of quite a stream of pure cold water from the mountains, and has an outlet into Yellowstone Lake. On the south side of the lake is a small mud-puff, steaming and fuming away, depositing various forms of sulphur. Two kinds of rock seem to be forming in its immediate vicinity; one a conglomerate from the surface-material. A careful study of the way in which rocks are decomposed and others formed from the resulting material by the hot steam and gases from the springs of this basin ought to throw light upon the dark subject of metamorphism.

On Pelican Creek, in the timber about six miles farther on, there is another system of depositing-springs, supplying a large mass of red earths and recently-formed rocks. An analysis showed the existence in those deposits of chromium, a rare mineral.

The trail down the mountain side was through a dense forest, very

* See Report of United States Geological Survey, 1871, and map of Yellowstone Lake, p. 101, and also same report for 1872.

much obstructed with fallen timber. Along Pelican Creek is a strip of rolling prairie, with marsh close by the stream, while near its junction with the lake the greater portion of its valley is marsh. This prairie is the home of great numbers of field mice and moles, which have burrowed up the ground to such an extent that it is traveled over with difficulty. The same is true of a great deal of the open country in the Yellowstone basin. Along the north shore of the lake the timber is interspersed with many grassy openings.

Tuesday, August 5.—I sent the pack-train to Fort Ellis for supplies. It was accompanied by Captain Noyes and the escort. Lieutenant Hall and a few men remained with us. There is very little, if any, danger from hostile Indians in the park at present. Small parties of Bannacks, Mountain Crows or Snakes, ("Sheep-eaters,") might try to steal something, but they are arrant cowards.

As far as my observation went, good camping-grounds for parties of ordinary size can be found almost anywhere in the basin.

At this camp a complete series of astronomical and hourly meteorological observations was instituted and continued during our stay.

Two p. m. found the beach sprinkled with explorers, spread out at full length, with strained eyes close to the sand, waiting for a crystal to "pop up." The sand is full of clear, sharp but diminutive crystals of different minerals, mostly silica. These crystals are perfectly shaped, and quite beautiful. They come from a porphyritic-trachyte porphyritic with glassy feldspar and silica, that occurs among the igneous rocks of this region. Much of the quartz is amethystine. The north shore of the lake has a long, shallow, sloping beach of soft sand, very convenient for bathing. The temperature of the water varies between 50° F. in the morning and 65° F. in the evening. It is influenced considerably by the heat of the sun, but at any time is cold enough to break down the constitution of the strongest bather if persistently applied. I have ventured to name this place Crystal Beach for the benefit of future poets and sentimentalists.

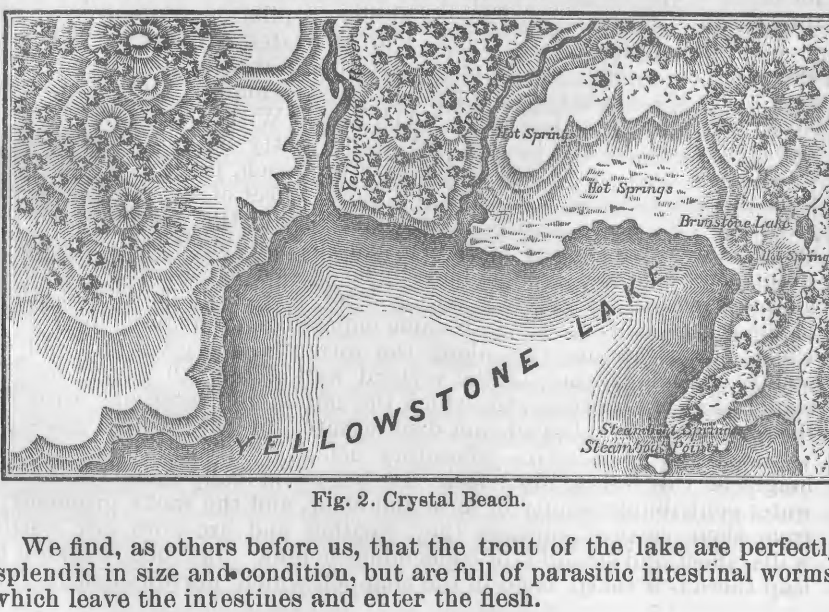


Fig. 2. Crystal Beach.

We find, as others before us, that the trout of the lake are perfectly splendid in size and condition, but are full of parasitic intestinal worms, which leave the intestines and enter the flesh.

The forest here is made up almost exclusively of pine, (*P. contorta.*) Toward the lake their branches are stunted and bent upward toward the trunk, while on the north side (from the lake) they grow out long and free. The contrast is very noticeable, showing that the prevailing storms come from the south (southwest?). This is to be expected as the basin is all open toward the south and west, and is completely hemmed in by high mountains on all other sides.

Thursday, August 7.—While breaking camp this morning a party of horsemen were discovered upon the other side of the river. They proved to be a party of officers from Fort Ellis.

After placing in a *cache* a lot of provisions and material, for which we did not have transportation, we started at 12 m. and marched fifteen miles to Yellowstone Falls. The river near the lake is not fordable, and generally between the lake and the falls is unfordable. Just below the mud volcano there is a ford that can be used late in the season. Our Indians stopped here, where they crossed the river to await our return upon the other side.

Two of my topographers started down the river upon a rude raft which they had constructed, expecting to get down to the falls before the main party. They were to sketch the stream and make soundings. Unfortunately about six miles below the lake they were swamped in some rapids, whose existence they had not discovered in time, and were obliged to abandon their raft, from which they escaped with much difficulty. They did not reach camp that night.

The trail is very good, about eight miles of it next to the falls being through open country. Some very fine springs occur opposite and a little below the mud volcano. Along the streams there is considerable marsh, and also along the river just above the rapids.

Friday, August 8.—Decided to remain at this camp two days. We are following the trail of Captain Noyes, which here runs into the direst confusion, branching off here and there, but each part always returning upon itself. They have evidently lost the trail and have been hunting for it. We had no guides who were conversant with the country about the lake, and I had trusted to our ability to pilot ourselves by the map of Captains Barlow and Heap, United States Engineers, who were here in 1871. I sent the guides out to find a continuation of the trail, and afterward visited the upper falls and examined the rocks in the cañon and about the falls with much care. With Lieutenant Blunt I went below the fall. This required some pretty nasty climbing along the water's edge about the immediate approach, perhaps not so much from the actual danger as from the moral effect of the terrible torrent just below, which seemed to clamor and roar at the prospect of a misstep by the human intruders upon a smooth, slimy shelf of rock, scarcely wider than the foot, which had to be passed at one place. Ten or fifteen feet from the mass of falling water, just on its flank, and a little to the rear, farther progress became impossible, for here the loose *débris* which occurs at intervals along the torrent's edge gives out, and one stands against the face of the vertical wall of the fall gazing into the cauldron of unknown depth, which the impinging water has worn into the igneous rock, softened and disintegrated by the heated gases and vapors from God's awful laboratory beneath. By the barometer the height of this fall is 150.2 feet. Its beauty is really remarkable. The water contributes beauty of form and color, and the rocks grandeur, as from their vertical jointage they weather and are worn into vertical walls, sheer and straight, of tremendous height. Just before taking the leap there is a sharp bend in the channel, which narrows considerably and wears out below, and to the right a huge semicircular precipice. The rocks are a porphyritic trachyte, and a loose conglomerate containing quite a large variety of igneous rocks. This conglomerate will repay future study.

We then went to the lower fall, but became separated on the way. He descended to the bottom of the cañon below, while my progress became obstructed at the verge of a precipice about 80 feet high, springing up from the seething waters close by the flank of the fall. The rocks, like those about the upper falls, weather vertically, and, from greater decomposition, into pinnacles and isolated slopes of *débris* lying thin on the softened and disintegrated surface.

I did not enjoy the sight of this fall at all, as my attention was constantly diverted to the steep and narrow gulch in the rock, at whose foot I stood, fearing that Lieutenant Blunt, whom I expected down every moment, might, by accident, start a loose stone from the *débris*, a mishap which would have inevitably knocked me into the waters below. Besides, there was just above me a huge drift of snow, and I began to feel certain that the time had come for it to be a small avalanche. I scrambled up the gulch with considerable difficulty, and soon found myself in camp with clothing thoroughly saturated from the spray about the falls.

During the early morning I had visited a mass of hot springs and gas-vents on the sides of a hill near camp. It seemed to me that I saw here evidences of the disintegration of the rocks by the hot waters, gases, and vapors from the springs.

I have noticed that whenever there is a mass of gaseous springs, either in action or extinct, if they come from a hill-side, the whole mass of rocks adjacent is disintegrated and of yellowish and white color.

Some of the party, while walking down the river along the edge of the grand cañon, stumbled across what is probably Captain Noyes's trail. Progress in this direction had been considered impossible. It afterward appeared that he had pushed ahead, making his own trail, after having lost half of one day in looking for the old one, which had become indistinct.

Saturday, August 9.—I sent back to the *cache* for extra supplies, and taking a small party, including Lieutenant Blunt, Mr. Hitt, and Mr. Putnam, returned to the lower fall, where we descended to the bottom of the grand cañon. We could not approach nearer than about 100 feet from the fall. The water in the river is quite high for this season, and probably at a low stage a nearer approach can be made; but not much nearer, for soon the rocks at the water's edge slope smooth and almost vertical into the torrent, and no *débris* can remain along the edge of such a tremendous current; besides, there is such a dense cloud of spray that nothing could be seen even if a nearer approach were made.

I have noticed no hot springs along the river between the falls, although there is abundant evidence of their former action; but immediately below the lower, or great falls, they are quite numerous, oozing and spouting from holes in the solid rock. Here I saw three that threw up slender columns (about half an inch in diameter) of very hot water, two or three feet high, like a fountain. The flow was continuous. A similar one across the river was just below the water's edge, and is only seen as the waves recede. Down the river little columns and clouds of steam gave evidence of the existence of numerous others. I infer that there are many of these hot gas and water springs, active and extinct, along the channel of the river through the grand cañon. Other explorers report their existence wherever they have reached the bottom of it.

Of those that we could examine, the greater number issued from clean holes in the hard, smooth, (water-worn,) rock. Probably the material deposited from the water gets washed off, while the gases stain the neighboring rocks. One spouting spring, however, had built for itself quite a symmetrical bee-hive-shaped mound of silica. An idea of the shape can be gained from the sketch below, (Fig. 3.)

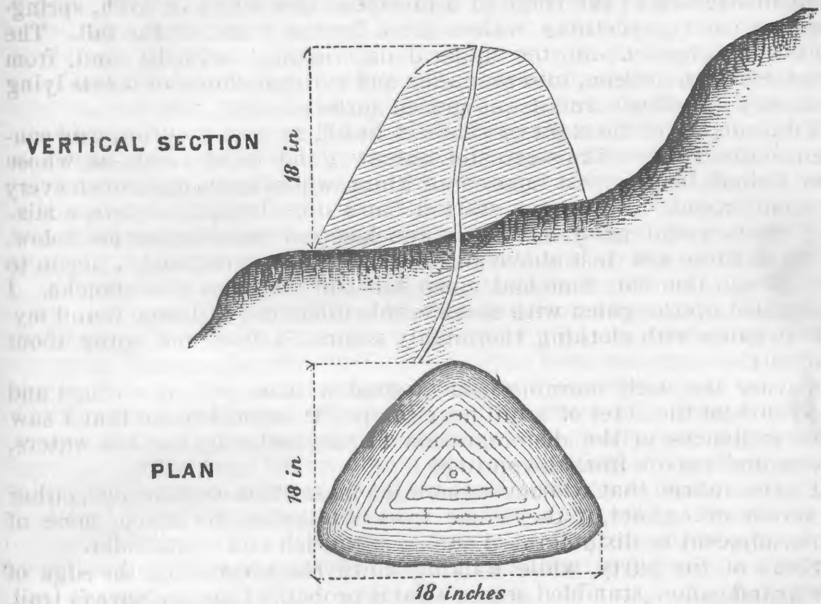


Fig. 3. Spouting Silica Spring, Yellowstone Falls.

By improvising a horizontal sight we set up the barometer at about the level of the bottom of the fall, after which we ascended to its crest. We were on the right bank, where there is a narrow ridge, very steep, with loose dirt on it, which leads down to the crest of the fall. We set up the barometer here, with the feet of the tripod in the water, at the only spot where the water's edge can be approached at all. The sharp ledge of rock here overhangs the precipice, and may fall off at some future day.

From this point one gets the fullest idea of the grandeur of the fall. The depth of the cut seems immense, and the effect is heightened by the tremendous vertical wall on the right, which has a sheer height of fully 500 feet. On the face of this mighty gash in the rocks the column of falling water dwindles and appears small, and this, perhaps, is the reason the effect of the fall is not so impressive from below, or even from the bottom of the cañon; the volume of water appears small in comparison with the great height and mass that encompass it. The fall is so great that the whole volume of water seems to break into drops and spray before it reaches the bottom, and the chasm for one-third of the height from the bottom is filled with a mass of white vapor which very much lessens the apparent height to the eye looking from below. But looking down from the crest, one gets the full effect of the great height. The chasm is so deep that the trees along the bank have but a slight effect in the beauty of the surroundings. The height of the great fall from our measurements (barometrical) is 328.7 feet. This differs from the results obtained by previous parties, but from the satisfactory manner in which our altitude work checked itself, I think it can be relied upon as a reasonable approximation. After examining the rocks from the top of the cañon above the upper fall to the bottom of that below the lower fall, with a view of arriving at an explanation of their origin and the attendant phenomena, I find that at the upper fall the rock is mostly a hard porphyritic trachyte, and Professor Comstock saw two or three dikes of trap. Higher up, and outcropping between the falls, a layer of coarse, soft sandstone, (conglomerate,) apparently horizontal, and distinctly stratified, occurs. It carries a good deal of obsidian in coarse grains, and its *débris* covers a good deal of the country on both sides of the river. Below this, and to the bottom of the upper cañon, occur an amygdaloidal conglomerate; a very coarse conglomerate, (rather breccia,) containing reddish-brown sandstone and obsidian, with well-marked cleavage; a coarse, friable stone, made up of grains of spherulitic obsidian; and the hard porphyritictrachyte observed above the fall. Between the falls I observed no marked change in the character of the rocks. A yellowish color appears over the whole just above the lower fall, but it is only on the outside, and is evidently a stain. About and in the Grand Cañon the rocks are nearly all tinged a brilliant yellow, and along the walls are weathered largely into pinnacles with their summits tinged reddish brown. Everywhere that I broke the rocks the fracture showed clearly that the yellow color was only a tinge, and revealed their igneous character, and I tested some of the most marked specimens. I found the same hard porphyritic trachyte and granular obsidian rock that occurs above. Close by the hot springs in the cañon the trachyte carries the strongest tinge of yellow, (sometimes whitish,) and is sometimes converted into a cellular rock, the imbedded crystals having evidently been destroyed.

I therefore suggest, in explanation of this phenomenon, that during a former period, when Yellowstone Lake covered a much more extensive area than now, the line now occupied by the river below the lake, especially from the falls downward through the Grand Cañon, became the line of escape for the hot gases, vapors, and chemical waters from the volcanic depths below; that their action softened and disintegrated the rocks until the waters of the lake could wear them away and form the present river-channel. There is evidently a sudden break in the quantity of this action at the falls, with its maximum effect below; consequently the Grand Cañon commences in a very marked manner. This view is further supported by the fact before alluded to, that generally where these hot springs come out of the side of a hill, that side is excessively eroded and the rocks stained yellow. In the deep tranverse gulches that lead into the Grand Cañon from the east, there is an excessive quantity of thermal and gaseous spring action. In many of these spots I have noticed what appeared to be solid rock, with the greatest similarity of outward contour to the undoubted igneous rocks close by, into which the finger could be thrust with ease, although the interior would be found very hot. A further examination than I had time to make would prove whether or not these are igneous rocks disintegrated by heat and chemical action, as I am much inclined to believe.

As the jointage is vertical, or nearly so, the walls of the cañon weather vertically.

Notwithstanding the remarkably extensive evidences of volcanic action, we have seen nothing yet that could be satisfactorily identified as an extinct crater.

Deer-flies, (a kind of horse-fly,) mosquitoes, and gnats are very numerous below the lake, and future travelers should be well supplied with netting, both for themselves and animals. They are not troublesome at night, owing to the cold. In other mountain localities they disappear with the extremely cold nights of July, but here, in the vicinity of the hot springs, they find plenty of warm rocks to roost upon when the nights are cold, so they can live on for an indefinite lateness of season.

Sunday, August 10.—Started on the march at 10 a. m., with the pack-mules very heavily loaded. The trail, for a considerable distance, follows close to the cañon through a dense wood, and is quite difficult. Marched twelve miles to Orange Creek. Much of the cargo had to be thrown off on the way, to be sent back for on the following day. The chief difficulty was in getting through the thick timber, which had not been sufficiently cleared away.

Monday, August 11.—Remained in camp. Provisions are getting low; sent back to the *cache* for what was left there. One of our cooks was lost in the forest, and remained out over night. I felt much worried, because it is a serious thing for a man to get lost in these forests as there are no landmarks visible from which he can determine his position.

Tuesday, August 12.—Sent parties out to the highest neighboring points to fire signals, and also sent out a guide to make a circuit around camp and find, if possible, the trail of the lost cook. Rain had been falling all night, and was still falling. Our efforts were successful, and the poor fellow came in about 10 a. m. in a pitiable plight, having had neither fire nor food. Rain was falling so hard that it was not considered advisable to move camp. It cleared up, however, by 1 p. m., when, with Lieutenant Hall, I started, with a few pack-mules and such of the cargo as was not required for immediate use, to carry it forward on the trail as far as possible. Our means of transportation were so limited that it took us two days to make one march. We moved fourteen miles to the East Fork divide, and returned to camp by sundown, leaving the cargo under proper guard.

Hot springs are very numerous along this trail, and the whole atmosphere is saturated with their vapors to that extent that we were somewhat nauseated by them. The trail follows for a while an old Indian trail, which, becoming too difficult, Captain Noyes had evidently abandoned it, and tried to get around by the head of the sharp ravines. It led in a very tortuous manner through heavy forests and over very steep hills. Along the bank of the Grand Cañon, by bridging a few of these ravines and deep gulches, a very easy road could be made.

Wednesday, August 13.—Broke camp at 9 a. m., and marched twenty-eight miles, directly over the highest point of the East Fork divide, to the East Fork of the Yellowstone River, one mile from the bridge over the latter stream. Through the ranchman at the bridge we have news of Captain Noyes and the train. Knowing that we would be short of provisions before he could get back to us, he had made a very rapid march into Fort Ellis and would probably get back to us in five or six days.

While on the high summit of the East Fork divide we were greeted with quite a severe mountain-storm. During the march along the trail among the numerous hot springs we were again nauseated as on the day before.

On Orange Creek, near our last camp, occurs a notable mass of springs that have so cut down and discolored the rocks that I named the locality Orange Rock Springs. Orange Creek is a wild mountain-stream, running at this point through a picturesque cañon whose walls are fully

200 feet high. From the bed and banks of the stream, and at the foot of the cañon walls, countless springs are issuing. The air is saturated with gases; the noise deafening, and the smell sickening. The spot has most of the physical characteristics of our best authenticated conceptions of hell; and one of our guides, who discovered it, did not tarry, for he felt certain that "the devil was not far off." The stream dashes over a series of rapids and cascades. The rocks are disintegrated and discolored with the greatest variety of hues—white, yellow, red, various shades of green, brown, and drab. Along the summit of the cañon walls lie huge blocks ready to drop off, while the foot of the slope is strewn with masses of fragments of the trachytic rock. On the northeast side, close by the water, is an exceedingly large jet of steam, escaping under such pressure from a narrow fissure that the noise is deafening. The steam smells of a sulphur gas, and is excessively hot. Close around it are three large hot springs with steam issuing from them, one of which is turbid white and quiet, while the other two are boiling and geyser-like. Very little water escapes from them by the surface into the stream. Directly across the stream, a little to the west, is a large boiling fountain spring, with an outlet whose channel is lined with silica. Besides, there are multitudes of small gas-jets, depositing sulphur in a variety of forms.

Where the trail crosses a small tributary of Broad Creek is another active mass of springs. Among them, one elliptical in shape and about 20 by 30 feet in opposite diameters, is quiet, has a whitish scum, and emits a sulphur gas. It has a slight overflow. Another of dark drab mud is 15 by 31 feet across, and is constantly in violent ebullition, throwing the mud 2 and 3 feet high. Steam and gas escape from it.

I decided to wait in this vicinity until the return of the train from Fort Ellis.

Thursday, August 14.—Sent back for the cargo left on the trail yesterday.

Across the stream, to the north from our camp, is a high ridge of granite, whose direction is not at first sight apparent. It runs across the creek close by camp, where it is quite low, and the surface *débris* can be seen for some distance to the south. A little east from us it shows two well-marked crags close by the south bank of the creek, which latter makes through it a sharp cañon, commencing about two miles from its mouth. About 200 yards farther up it cuts through a layer of sandstone, carrying numerous fossil plants, which rest upon a bed of volcanic conglomerate. This latter crops out extensively along the stream above, and its *débris* is scattered over the rounded hills to the south. It is certainly peculiar. We have seen it in varied conditions and structure. All of the way across, from one side of the mountains to the other, at the Washakee Needles, and, in fact, everywhere that we have come in contact with these mountains, it can be recognized in the distance by its columnar and fantastic weathering, and somber brown, sometimes almost black, hue. It is made up of a smoothly-rounded *débris* of a great variety of volcanic rocks, in sizes varying from a pebble to enormous bowlders. I have seen these latter in position that were from 10 to 15 feet in diameter, and others that clearly came from it very much larger. Along this stream it carries large bowlders of granite and basalt. Being so near to the granite ridge just mentioned, I was doubtful about the source of the granite bowlders until I found a huge one in the bed of the stream with some of the matrix still clinging to it, and shortly afterward numbers of them stuck along a vertical wall of the conglomerate. It is probable that the blocks of granite strewn over the country south from camp are from this source, because they appear to be rounded from wear rather than from concretionary structure, while the granite of the ridge is lamellar, and gneissic in structure. A notable feature of the conglomerate is, that it is frequently stained and its constituents sometimes thoroughly impregnated with a green mineral (silicate of iron,) which might easily be mistaken for carbonate of copper.

As far up East Fork as can be seen from these granite knobs the valley is quite open, fairly timbered with spruce, pine, and aspen, and is clothed with excellent grass on the rolling country between the cañons where the stream cuts through some minor ridges. On these there are many ponds of stagnant water. To the north and northeast the mountains are very high and rugged.

Friday, August 15.—I started at 7 a. m. with a small party, carrying rations and bedding on our saddles, for the Great Hot Springs on Gardiner's River, distant twenty miles down the Yellowstone. We made our nooning near a lovely fall on the east fork of Gardiner's River, after traversing a beautiful country of high, rolling hills, well watered, with excellent grass everywhere, and wood scattered here and there in groves and masses. At the fall the rock is basalt, stained to a dull yellowish hue. The weathering about it and in the cañon below is quite similar to that about the Upper Falls of the Yellowstone.

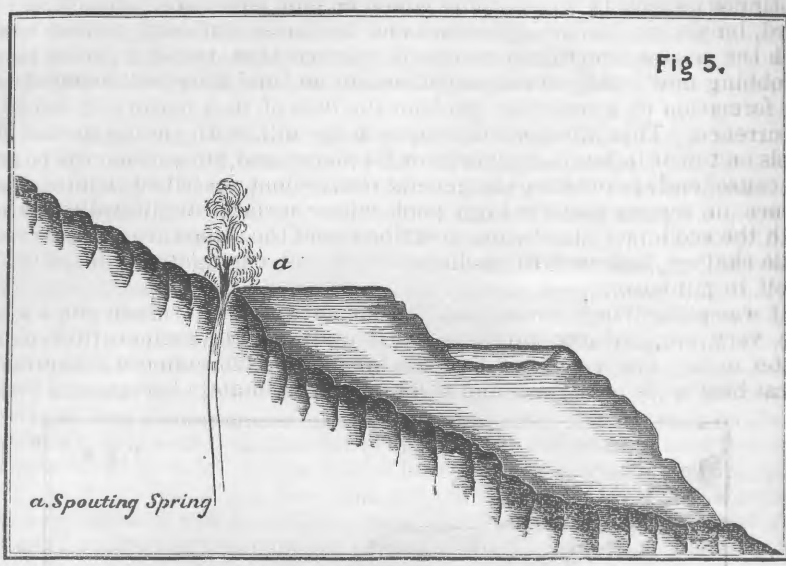
A beautiful effect is produced about half-way down the face of the fall, where a horizontal dish-like ledge juts out from the wall. Some of the falling water rushes down and into the dish of the ledge, so that its impetus throws it up again at several points in low, heavy, fountain-like jets, while another portion jumps clear over and beyond the ledge, in a thin transparent sheet whose convex surface looks exceedingly like a glass cover preserving the little fountains beneath from defilement.

We reached the springs at 3 p. m., and spent the afternoon in looking over this very interesting and beautiful phenomenon. A settlement has sprung up here for the purpose of accommodating sight-seers and bathers. I have not much confidence in the bathing properties of the water.

Saturday, August 16.—Completed an examination of the springs and the surrounding country, and started back to camp, which we reached at 8.30 p. m. As the Great Hot Springs have been described and thoroughly photographed, I will only offer an explanation of their structure, as my views materially differ from any that I have yet seen advanced. The maximum temperature of the water given (164° F.) was obtained by Dr. Heizmann and myself by penetrating through the clouds of steam and over the hot and dangerous crust to the main fissure, from which the water was escaping with considerable violence. Looking back at this performance it seems foolhardy; for no one can tell, in such a mass of steam, whether the crust under their feet about the edge of the fissure is firm, or thin and overhanging, a common feature. These springs (see sketch, Fig. 4) are the source of a small stream which empties into a sink near Gardiner's River, a short distance above where the latter joins the Yellowstone. The water comes out at temperatures varying from 92° F. to 164° F.; the latter at the fissure, where the maximum quantity of water is escaping now, and is strongly impregnated with certain minerals, principally calcite, which latter it deposits profusely upon exposure in thin layers to the atmosphere. The springs originally came out at the top of the hill above them, which I should judge to be fully 1,000 feet above those in action now.

The effect of the rapid deposition from the water is quite remarkable, there being formed by this agency level-topped hills, sometimes 200 feet high in successive terraces, one below the other down the slope of the hill—probably along a line of rupture in the rocks—their faces showing

Fig 5.



Ideal section of spring and its deposits.

beautifully corrugated surfaces which imitate very closely the Meandrina coral, and display, while the water is flowing over in thin sheets, delicate and coarse tints of carmine, pink, rose, yellow, and brown.

The proof that the progress of these formations is from the *top downward*, and not from the bottom upward, as explained by Professor Hayden,* is conclusive; at the top, the springs are all dead, and the deposits are decayed and almost hidden beneath vegetable loam from the dense forrest that has overgrown them, while *all of the active springs* are at or near the bottom. He saw the dead remains at the top, but after observing closely their characteristics as hot-spring deposits, he falls into the strange error of saying: "But in what manner was it formed? I believe that the limestone was precipitated in the bottom of a lake, which was filled with hot springs, much as the calcareous matter is laid down in the bottom of the ocean at the present time. * * * * * The deposit was evidently laid down on a nearly level surface and the strata are horizontal."

After the water ceases flowing the surface bleaches snow-white or bluish-gray.

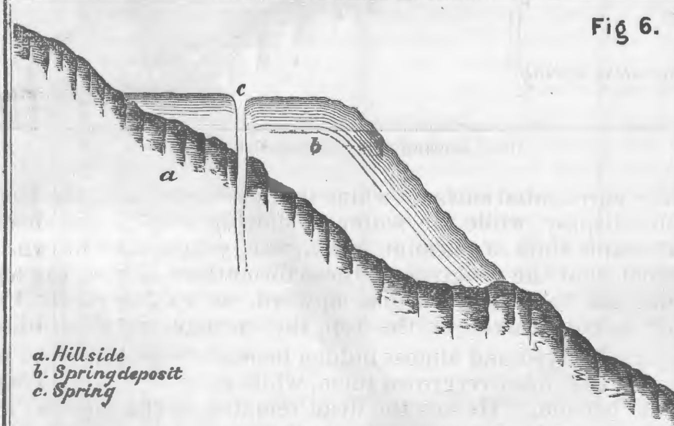
The process commences with the water running from one hole or fissure, (Fig. 5,) or several, under sufficient pressure to rise as a column to a height varying with the pressure, and from thence flowing off down the hill, with its surface covered with concentric ripples, caused by pulsations in the current; along the scolloped lines of these ripples lie the minimums of velocity in the flow, and the maximums of deposition of sediment; consequently, little wave-lines of ridges commence forming very soon, and once started, another check to the velocity is introduced whose value is continuously increasing. This, in time, makes shallow pools, which are soon filled up with sediment, and in time the upper

* Report United States Geological Survey, 1871, p. 68; ibid., 72.

ones merge into one large one around and below the orifice, on a level with it and bordered by a scolloped rim, over which the water flows in a continuous sheet, (Fig. 5.) The water flowing over this rim and downward, builds up, as the rim rises and advances outward, a steep slope with the maze of corrugations on its surface that result from its rapid throbbing flow. Any serious obstruction on this slope will bring about the formation of a seconday pool on the face of it, a feature of common occurrence. This process builds up a large hill, with the large shallow pools on top of it, but everywhere on its slopes and top-surface the slightest cause tends to produce the general results just described in miniature. Hence, on top we find the large pools whose surfaces are literally meshed with the scolloped rims before described, and the slopes are studded with little shallow basins with scolloped rims and corrugated sides, the hill itself in miniature.

It was along these rims that Dr. Heizmann and I made our way to the very edge of the largest orifice and took the temperature of the water in it. The spring thus builds for itself a characteristic mound of great beauty, both of form and color, which ultimately becomes its tomb.

Fig 6.



a. Hillside
b. Spring deposit
c. Spring

For, in due course of time, the level surface about the orifice becomes raised so high that the water can no longer flow out and over it, whereupon the deposition gradually chokes it up with thin, cellular curved layers of calcite.

Now, if the cause of this action were continuous and of constant power, the spring would break out again in a favorable spot, and build up another mound of about the same height, and the process would be repeated so long as there remained any possible means of escape for the confined waters in that locality. But, although the cause is thus far continuous, the power is actually decreasing, as is evidenced by the extensive distribution of the dead relics of former volcanoes and the multitude of extinct and waning thermal springs; consequently, where the spring breaks out afresh, it must, in this case, be at some point lower down, as the line of rupture in the crust of surface-rock evidently runs downward toward Gardiner's River, and a new mound will be built up of less height than the last one. Sometimes small vents have broken out below the level of maximum action, producing a fountain-spring, throwing a jet of water nearly as high as the level of the principal spring. The deposition from this would produce a cylindrical column, with the top narrower and rounded. (Fig. 7.)

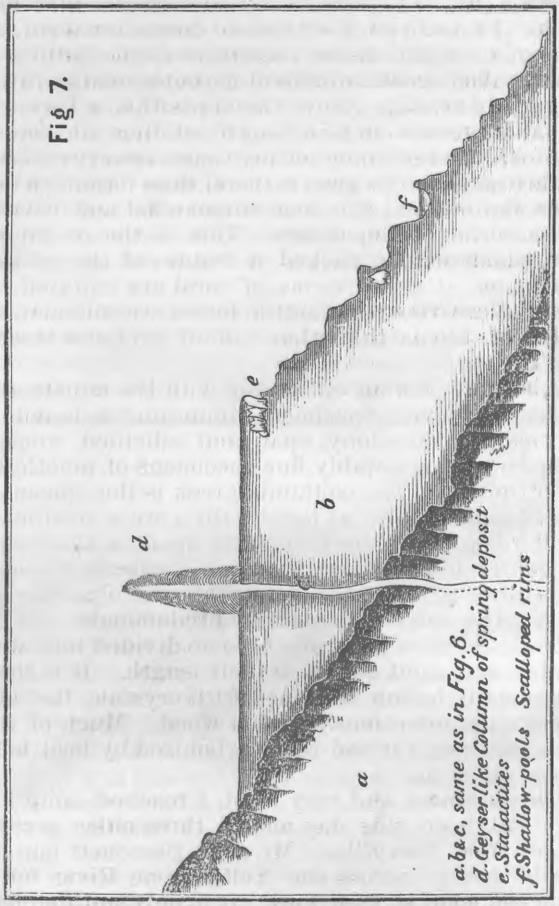


Fig 7.

a.b.&c. same as in Fig. 6.
d. Geyser like Column of spring deposit
e. Stalactites
f. Shallow-pools Scalloped rims

Ideal section, illustrating the formation of the Liberty Cap

The "Liberty Cap" described by Hayden, and a similar column near it, are illustrations of this, and there are other examples higher up. If, instead of such an orifice, there should be a narrow fissure, a sharp, rounded ridge would result, of which there are numerous examples. Local circumstances may concentrate the force in certain small orifices or fissures, and thus keep up the action in a feeble manner at a level where the principal action is extinct. Thus there is now feeble action on three or four levels above the principal one, which at one place has produced an illustration of all the structural peculiarities on a diminutive scale.

Sometimes the water has found a vent lower down, before the orifices above have closed over, thus leaving the craters bare, displaying numerous small caves.

I infer that the hill of maximum action now has about reached maturity, from the fact that the water from the principal orifice is only thrown a little above the surface. We may, therefore, expect springs to break out lower down the hill, if indeed they have not already done so.

Among the peculiarities of deposition are delicately-beautiful hollow spheres, about one-eighth of an inch in diameter, sometimes open on the top, with a lid. They are so thin and fragile as to break at the slightest touch. I put forward with some hesitation a curious explanation of their origin. From the soft sediment at the bottom of the pools about the main orifice, small bubbles of carbonic-acid gas are constantly but quite sluggishly arising. Now, the deposition is here so rapid that any bubble that lingers a certain length of time on the bottom—as many of them can be seen doing at any time—receives a coat of it over its film of surface sufficient to keep it there, thus forming a fossil bubble. Lying there on the bottom, it is soon surrounded and covered up with the ordinary material of deposition. This is the origin of the small spherical cells which are so marked a feature of the rocks deposited from these springs. Certain forms of coral are imitated, notably the *Madrepores* and *Meandrina*; stalactitic forms are common, and the soft deposit in the pools seems to harden into an irregular interlaced mass of strings and fibers.

Sunday, August 17.—I went out to-day with the miners at the bridge to a place called by them "Specimen Mountain," a noted locality for amethysts, forms of chalcedony, opal, and silicified wood. We were fortunate in finding some notably fine specimens of amethysts and yellow crystals of quartz. The containing-rock is the igneous conglomerate, before mentioned. In it, at this locality, are a good many silicified trees, the hollows of which are frequently lined, in short sections, with varieties of quartz in very beautiful and perfectly-preserved crystal forms; rock-crystal, yellow, blue, amethyst, and opal, and many kinds of chalcedony. The amethysts seem to predominate. In the process of silicification these trees generally become divided into short sections by cleavage planes at right angles to their length. It is these sections that are occasionally hollow and lined with crystals, the adjacent sections being plain, unpretentious petrified wood. Much of the latter is perfectly black, as though it had been carbonized by heat before the fossilizing material came in.

Loaded with specimens and very tired, I reached camp a little after dark. Camp had been this day moved three miles across the river, to meet the train from Fort Ellis. Mr. John Barronett has built here a very substantial bridge across the Yellowstone River for the use of miners visiting the head at East Fork. It is only suitable now for pack-animals.

Monday, August 18.—Pack-train in charge of Lieutenant Young arrived at 3 p. m. from Fort Ellis, with twenty days' supplies for the escort and twenty days' supplies for my working-party.

Tuesday, August 19.—Moved camp seventeen miles, across the Elephant's-back Mountains to Yellowstone Falls. The trail proved very bad; many animals fell down hill, and there was considerable bad bog. The train was pretty badly used up, and two mules were lost; all this, too, after leaving half the cargo at the old camp to be sent back for. The odometer is again in use, having been repaired at Fort Ellis. Camped on Cascade Creek. Along the trail the country is pretty open north of the mountains, with excellent grass, plenty of water, and groves of trees. Across the divide the forest is quite thick, with small openings of meadow, There are three trails across the divide, and we unfortunately took the worst one. I made the ascent of Mount Wash burne with a topographical party.

Wednesday, August 20.—Sent back to the old camp for the cargo left behind yesterday. The lost mules were found. Lieutenant Kingsbury with the escort arrived at 2 p. m. from Fort Ellis; they had staid behind to get their horses shod. Captain Noyes had been taken sick and could not join us. He proposes to meet us at Camp Brown.

Thursday, August 21.—We remained in camp, shoeing the animals and resting them. Rain fell during the whole day. Sent to the *cache* for the remainder of the cargo left there.

Friday, August 22.—In camp; rained all day.

Saturday, August 23.—Moved camp thirteen miles to the Hot Springs, on Warm Spring Creek, where it emerges from the timbered hills. The Indians were in camp on this stream waiting for us. Our party, with the exception of Captain Noyes, was now altogether again. The country along this creek, for about eight miles from Yellowstone River, is an open, rolling prairie, extensively burrowed by moles and field-mice. About the springs the water of the creek and its tributaries is either hot or sour, frequently both. We found good water, after a little search, in a marsh above the springs, on the South Fork.

Sunday, August 24.—Marched 13.3 miles across the divide between the Yellowstone and the Madison, to the Lower Geyser Basin, on Fire-Hole River; met two parties of sight-seers from Montana. The trail passes by a small lake, very near the summit, and down a sharp but short hill, on the west side of the divide, and soon strikes the waters of the Madison. The size of this stream has been exaggerated; it is from two to three feet deep. A depth of 10 feet, as reported, would overflow its banks and the whole valley. Along this stream there is a good deal of marsh, meadow and many groves of timber. Good water can be easily found in the Geyser Basin by hunting for it.

Monday, August 25.—Marched ten miles to the Upper Geyser Basin. The trail from the Lower to the Upper Geyser Basins is very bad from marsh; with a little trouble it could be carried along the hillside through the timber and made very good. Fire-Hole River is the principal East Fork of the Madison. Its waters in the Geyser region are generally quite warm, sometimes hot; just above Old Faithful, in the Upper Basin, it becomes cool and potable again.

The boiling water from the silica springs was used for cooking and found very convenient. The structure of the geysers or silica springs is quite similar to that of the calcite springs on Gardner's River, except that the silica deposits slowly, while the calcite deposits rapidly, making a corresponding difference in the size and shape of the mounds formed. There is a good deal of silica (geyserite) about the springs in a soft, pasty condition from solution in the presence of alkaline salts, which ought to throw light upon the formation of chalcedony. Other explorers have devoted much of their time and attention to the description and explanation of these geysers and springs, to which, in my hasty visit, I have seen nothing to add. Further elucidation must be the result of careful observation and study, over greater periods of time than are at the disposal of exploring parties; besides, the question of getting back to Camp Brown is becoming rather serious; the pack-train is badly used up, from traveling excessively laden, over bad trails, (the cargoes average over 250 pounds,) and there is considerable doubt whether the rations will hold out while we are making way through the "impassable" country at the head of Wind River, described by our forerunners.

The immediate difficulty, however, is, that the Indians have failed to find the trail back to Yellowstone Lake. They seem to be nonplussed and are depending upon me, and this evening informed me that we were lost. The explanation of this is, that they are "plains Indians," and are wholly unaccustomed to travel among forests like these, where all landmarks disappear. It will, therefore, be necessary to make a trail—no pleasant prospect in such a country, where one has so many people and animals dragging along after, to multiply the consequences of getting caught out in the dense forest without any camping-place. An individual or an animal might easily stray a short distance from the trail and get lost, if there was any halting or confusion, and to get lost in this dense forest, where the hills are so rounded that nothing can be seen from their tops, would be a terribly serious matter.

Tuesday, August 26.—Taking a picked party of Indians, the guide Smith, and the escort as pioneers to blaze and clear the trail, I started out early in the morning, with the intention of making a trail to Yellowstone Lake, if the old one could not be found. The train was to wait until 10 o'clock before starting. After a short and fruitless search I took out a compass, and giving the Indians the direction, told them to go that way all the time, and pick out the best way. This they did with great skill, but as our route lay directly across the water-drainage, the hills were frequent, and the trail pretty rough.

An Indian seems to have an instinct which enables him to pick out the best country to travel over, and to avoid natural obstacles.

Four p. m. found the advance party at the lake, at the spot we had set out for, but it was perfectly certain that the train would have to stop on the way. Fortunately there were suitable camping-places along the trail. With empty stomachs, and saddle-blanket lodgings, we made a large fire, and spent a remarkably long night in vain efforts at sleep.

Wednesday, August 27.—The minimum thermometer last night registered 13° F., the greatest cold we have yet experienced. At 8 a. m. an orderly arrived with a message from Lieutenant Hall, commanding the escort, informing me that the mules of the train were so badly used up that it could not move to-day. Much of the cargo had been thrown off along the trail, and one loaded mule was lost. Later in the morning Lieutenant Hall himself arrived and further informed me of the state of affairs. The odometer-cart had worn out completely and was abandoned. The packers had gone back on the trail to gather up the cargo and find the lost mule. Sending all back to camp except the Indians, my orderly, and the guide, I remained to look up the trail ahead.

By noon, having gone without food since morning of the day before, the pangs of hunger overcame a violent prejudice and I ate some fish from the lake worms and all. The Indians have been eating these wormy fish all along and I doubt whether there is anything injurious about them. I might have obtained something to eat from them, but there is a feeling in the average white man's breast which prevents him from asking such a favor from an Indian. It is very unreasonable, but it is there. The Indian, on the other hand, asks favors from the white man, feeling within himself that all that the white man has belongs to him, and he is therefore only getting back his own. He never returns thanks for such favors.

The principal difficulty on the trail yesterday was that it was not sufficiently cleared to allow the pack-mules to get through without getting frequently stuck between trees—a mishap in which a mule will waste strength enough to carry him and his pack several miles.

I have often been struck with the philosophical way that a packer proceeds from the grass that a mule eats to the work that it will do. In his eyes so much grass represents so much mule-work, and no grass represents pretty nearly no work, while it is true that very little work can be expected of a train of pack-mules that have not eaten pretty nearly their fill of grass or something else before starting.

Thursday, August 28.—The train came in during the morning and went into camp at the Hot Springs on the lake three miles ahead. The trail was good, but somewhat obstructed with timber along the shore of the lake. There is a first-rate trail along the west side of the lake, over which I would have sent the greater part of the expedition had I known of its existence, thus avoiding the Fire-Hole Basin, and our trials in getting away from it. It would have been perfectly easy to get a small party from that basin to the lake.

Along the west shore of the lake are numerous small streams with meadows and marsh.

The lost mule, with a cargo of flour, beans, and coffee, was not found yesterday, although the search was carried back to our camp in the Fire-Hole Basin. Word was left with some gentlemen visiting the geysers, who were coming across on our trail, to take this mule back to Fort Ellis in case it should find its way back to the trail before they came along. Our rations were too short to permit any more time to be spent in search and it was therefore abandoned.*

The flour belonged to the escort and is a severe loss, necessitating half rations of bread for them during the remainder of the trip.

At night the Indians in camp up the valley had a scalp-dance over two Sioux scalps that had been given by the Crows to two of the Indians with Captain Noyes's party going to Fort Ellis, who had visited the Crow agency. They invited everybody to join, which invitation was eagerly accepted by the young men of my party, the guides, packers, and soldiers. This dance gives every one a chance to sing and yell with all his might, and they literally made the welkin howl. There was considerable lung-power in action. The waves of sound were echoed back and forth from the woods and hills on either side of the narrow grassy valley, and came billowing to the lake with a tremendous effect, which was heightened by the lurid glare from the numerous camp-fires standing out in the darkness against the mass of black forest behind. The West Pointers in the party called it "Our twenty-eighth hop."

Friday, August 29.—I made arrangements for the main party to move along the south shore of the lake toward the river, and started at 11 a. m. with Professor Comstock and a topographical party to make the ascent of Mount Sheridan, about ten miles south of the lake.

The country is covered with a dense mass of timber on low rounded hills, with the fallen timber so bad as to make much of the country impassable for animals. There was no trail and no one who knew anything about the country. I went ahead, steering by the compass, going around the masses of fallen timber and picking out the highest ground and ridges to travel over. We were lucky enough to make camp at the foot of the mountain after a march of between three and four hours. We could not see it at all at starting, and only caught one glimpse of it on the way before we came directly upon it, and yet it towers to a height of 3,000 feet above the surrounding country.

Saturday, August 30.—Started up the mountain 7 a. m.; a very late start for such work. As there was no chance to reconnoiter, we had the ill luck to take the longest and most laborious line of ascent. The party becoming separated, to my great surprise I reached the summit first at 9.45 a. m., and the rest of the party an hour later. Thinking myself

* This mule was found by them and turned in to the quartermaster at Fort Ellis.

behind I had made great haste so as to reach the summit before the others were ready to come down.

Mount Sheridan is a high mountain mass, rising alone from the rapidly sloping hills of the Snake River drainage, just south of the Yellowstone divide. All the rocks seen were igneous, sometimes stained and decomposed from hot-spring action. Springs and feeble geysers being still in action along the streams from its north and east slopes.

To the east and southeast is a ridge of high timbered hills, which sweeps around to the northward and terminates in Promontory Point at the south end of the lake. To the south, as far as the Wind River range, about sixty miles distant, the country is a mass of high timbered ridges, formed by the erosion of the waters of Snake River, all rapidly sloping down to the eastern base of the Tetons, which lie south 10° west, about forty miles distant.

Westward, and from the Tetons, there are no mountains, only low, rounded, heavily-timbered hills, as far as the eye can reach. To the northwest commence the high ridges of bald mountains which lie between the different tributaries of the Gallatin and Madison Rivers. Between Mount Sheridan and the lake, the divide between the Snake and Yellowstone waters—the Continental Divide—is certainly not more than 300 feet above the lake, and in many places runs within a mile of the latter. It is a broad, comparatively low, gently rounded stretch of country, so flat on top that the opposite-shedding waters are frequently interlocked. It is dotted with lakes, some quite large, and carries a good deal of marsh and strips of meadow along the streams. All of the lakes in sight, except one, drain into the Snake River.

The divide between the waters of the Madison and the Yellowstone, above the falls, is a stretch of smooth hills, rising but little above the Yellowstone Basin, and having steep, rocky slopes only in few places. All of the country in the basin about Yellowstone Lake and extending far to the westward is very densely timbered, with only small openings along the streams and about the marshes.

There is a great deal of fallen timber, such as to sometimes completely obstruct progress, but I have observed that the most and the worst of it lies in the immediate neighborhood of water, either in lake, stream, or marsh, and can be very largely avoided by traveling high up on the hills and ridges. Along the shores of Yellowstone Lake a great deal of water is held in the numerous swamps which afford a constant supply to the multitude of small brooks feeding into the lake. There is, consequently, here an excessive quantity of fallen timber.

The huge mass of the Sierra Shoshonee Mountains closes in and around to the northward of the basin, showing a comparatively low granite ridge running from the East Fork with a northerly trend down the right bank of the Yellowstone River. The highest portion of this mass seems to be that northeast from the basin, about the headwaters of Clark's Fork and the Rosebud. Northward from there it soon runs out and makes way for the valley of the Lower Yellowstone River. Its structure seems to be buried beneath the most extensive outpouring of lava and volcanic matter yet observed on the globe. Along its eastern base we gained only an inkling of its structure from the dip of the upper-lying rocks. Probably the key lies in the country on the Muscle-Shell River, to the northward. It is probable that the southern portion of this volcanic overflow at one time overlaid the northeastern slopes of the Wind River range, and that the erosion of the drift period has cut a channel through on this flank, forming the Wind River Valley and leaving the extensive deposits of volcanic *débris* in the valley as well as tremendous precipices of castellated basalt, trachytes, conglomerates, and sandstones that fringe and seemingly seal its head and northern border. I had the topography of the country in sight from this station sketched with great care and reasonable precision. It is the best geodetic station in the region traversed. My topographical party has now inspected the Yellowstone Lake Basin from mountain-peaks favorably situated on its eastern, northern, and southern borders.

We commenced the descent at 12.30 p. m., and as soon as possible took up the march for the main party. Their trail was struck at 5 p. m., and followed until sundown, when we camped on the spot they had left in the morning.

The smoke was still rising from the smouldering fires and the ground still fresh on their departing trail. As I rode up to the scene so lately rife with the jest; the coarse shouts of laughter; the murmuring of many voices; the bugle's blast; the loud words of command; the round-toned, cadenced shouts of the Indians; the shrill, clarionet-like cry of the squaws; the crying of papooses; the barking of dogs; neighing of horses; braying of mules; the roaring and crackling of great camp-fires; and the occasional rifle or pistol shot at some misguided squirrel—it seemed utterly cheerless and desolate. What can appear more desolate than a freshly-deserted camp?

Sunday, August 31.—We have now only twelve days' rations, and between us and Camp Brown is the "impassable barrier never scaled by white man or Indians." If it were not for the question of provisions I would laugh at it, because we have an outfit that can go almost anywhere; but the question of time now assumes an unhappy importance, and I begin to feel much worried.

We arose at daylight, cooked a hasty breakfast, and started off at sunrise, overtaking the main party at 9 a. m. on Yellowstone Lake, just as they were preparing to start on the march. They had made one march of ten miles over a good trail, and the one of the day before of nine miles, which had been beset with difficulties, owing to the attempt to follow the lake-shore too closely. There was no trail, but a great deal of marsh and fallen timber.

Owing to some misunderstanding, the Indians had become angry with Lieutenant Hall, and considerable jealousy had sprung up among themselves, whereat the greater portion of them had left our camp and gone off.

After a short rest I started off with the guides to make a trail. It was pretty rough for a few miles, but after that we struck a good trail, with many freshly-blazed trees marking it. A queer freak of the disaffected Indians was here displayed. They had deserted the main party and gone on ahead, when, finding this excellent trail, they had freely blazed it with their hunting-knives for quite a distance until the work and slow progress involved became monotonous. I regarded this as an olive-branch, and treated them very kindly, as though nothing had happened, when we passed them. They staid away two or three days and then came back in driblets, but I never, by word or sign, let them know that their absence had been thought of. Their own jealousy continued a few days longer, and then everything went on as happily as before.

We marched ten miles and camped at the extremity of the arm of the lake that we left this morning. There is a well-marked beach along this shore of the lake, but it is frequently deceptive and dangerous from quicksands where the water comes in from marshes above; the timber gradually becomes more open and meadows replace the swamps; the country to the south rises rapidly into hills of considerable magnitude, and the water drains off too rapidly to permit the formation of much marsh.

Monday, September 1.—Broke camp and marched ten miles into the valley of the Upper Yellowstone River. The trail strikes the southeast arm of the lake, thence following up the valley of a small tributary of the lake whose course is parallel to the river to a point high up on the hills bordering the west side of the valley. The latter part is pretty bad from marsh and underbrush. Our camp was about ten miles from the mouth of the river.

The valley about the mouth is very marshy, with numerous small ponds and sloughs. There is also a great deal of timber on the low grounds on the west side, but from its proximity to water there must be in it a great deal of fallen timber to impede progress.

While the advance was quietly following a first-rate trail, it was suddenly observed to lead up a high hill to our right. I sent an Indian to see what became of it up there, who came back with the information that it led to an open rocky place on top, and was after that "kaywut," (played out.) It now appeared that the top of the hill was used as a stamping-ground for elk, and they had made such a broad trail leading up to it as to completely deceive us. Sending back word to the train to go into camp, we started in search of our lost trail, which was soon found considerably lower down in the valley.

We have now reached a country from which one of our Indians says he knows the way back to Camp Brown by the head of Wind River. He belongs to a band of Shoshones called "Sheep-eaters," who have been forced to live for a number of years in the mountains away from the tribe. A heavy rain-storm set in about night-fall.

Tuesday, September 2.—Broke camp a. m. and marched up the Yellowstone River thirteen miles. The trail leaves the timber and goes into the open valley. This latter is probably quite marshy earlier in the season. It is also probable that the river is not fordable in the spring.

The storm of last night burst out about noon with great violence and continued during the day and night. A good deal of snow fell in the mountains about 1,000 feet above us.

We camped in the edge of a grove of pines with a dense fringe of fallen timber on its border. It was a cold, wet camp in the border of the timber, and considerably mixed withal. As it was raining hard when we reached it, everybody dropped into the first place that presented itself; the fallen timber monopolized nearly all of the ground, so that there was little choice; the result was, that Indians, soldiers, citizens, and officers were all camped together in the direst confusion, on a small spot that it seemed possible almost to cover with a blanket.

All through this basin game-tracks have been very abundant, but our party from its size makes a good deal of noise, which will account for the fact that we did not see a great deal. A magnificent elk crossed the valley in advance of us, and in plain sight to-day. He was a royal fellow, indeed, and seemed to resent our intrusion upon his chosen rutting-ground. The party was too much drenched and too cold from the driving rain to make any attempt to get him; the first instance of the escape of anything (except bear) that came in sight of it. The trail was very good except the last mile, which was quite marshy.

Wednesday, September 3.—The storm continued. Broke camp 8 a. m. and marched thirteen miles. The trail soon leaves the main stream and follows up a small tributary that comes in from a little west of south, crossing a low divide to a tributary of the Snake.

At this divide occurs a curious phenomenon, probably the one referred to by the early trappers as the "Two Ocean Pass."

Marching at the head of the column where the trail approached the summit, I noticed that the riband of meadow in which the stream lay we had been following suddenly dropped away in front of us with a contrary slope. I could still see the stream threading it, and for a moment could scarcely believe my eyes. It seemed as if the stream was running up over this divide and down into the Yellowstone behind us. A hasty examination in the face of the driving storm revealed a phenomenon less startling perhaps, but still of remarkable interest. A small stream coming down from the mountains to our left I found separating its waters in the meadow where we stood, sending one portion into the stream ahead of us, and the other into the one behind us—the one following its destiny through the Snake and Columbia Rivers back to its home in the Pacific; the other, through the Yellowstone and Missouri, seeking the foreign water of the Atlantic by one of the longest voyages known to running water. On the Snake River side of the divide the stream becomes comparatively large at once, being fed by many springs, and a great deal of marsh.

While the small advance party were approaching camp two of our Indians discovering three elk close by gave us an illustration of skillful hunting by crawling up and killing the three with four rifle-shots. They were extremely large and fat. As examples of Indian generosity to white men are becoming rare, I wish to put on record this one where one of them made me a present of the whole carcass of one of these elk. Being hungry enough to eat it all myself, after the long march in the cold rain, I had a vivid appreciation of the gift.

The trail was good, passing around a beautiful lake in the Yellowstone Valley, which is probably the Bridger Lake of the old maps.

The valley of the Upper Yellowstone is quite flat, and lies between grand and rugged walls of bare, broad mountains of volcanic *ejectamenta*. It is from one to three miles wide, and interspersed with broad meadows, and groves of pine and spruce. The amount of water that it receives from the slopes on either side is astonishing, and accounts sufficiently for its marshy character.

There is a remarkable discrepancy between the volumne of water in the river above and below the lake. The storm prevented us from making observations for a comparison, and I can only say that above the lake the stream seems ridiculously small compared to what it is below. The volume of water which the lake receives from small streams and the numberless marshes along its border must be very great.

Thursday, *September* 4.—There is only one Indian in the party who knows the country between here and Wind River, and he seems to be getting proud of the power he has over us and wants to exercise it a little. When all ready for the start it was discovered that he was enjoying all the comforts of a home in the bosom of his family and taking a quiet smoke after having been told to get ready an hour before. Here was a dilemma. It was his second offense, and must be noticed, but to rebuke him and rouse his anger might be followed by his certain departure, followed in all likelihood by all of his dusky brethren. It was no easy matter to make them understand us when we were perfectly quiet. How much misapprehension must occur in case all should become excited and angry. I sent another message to him, and rode along myself trying to look solemn and determined during its delivery. To our great gratification he surlily saddled up his pony and struck off on the trail, assuming from thence forward a winning smile and air of boyish oblivion.

We marched fourteen miles across the high rolling outliers of the Sierra Shoshonee, with the mountains close on our left, and camped on another tributary of Snake River.

The hills between the valleys are quite large but considerably worn, so as to present accessible slopes. The dense timber which has caused us so much trouble and labor is rapidly thinning out so that the trail can be picked out mostly clear of it. Magnificent slopes of grass and luxuriant flowers are becoming numerous.

In getting through the timber and over the terrible trails that we have seen so much of, it has been my custom to start first on the march with a small party, consisting of the guides, a few of the best Indians, and two soldiers with hatchets to blaze our trail. Immediately after comes a pioneer-party from the escort with axes and shovels to clear the trail that has been blazed; cutting away trees and fallen timber; cutting down steep banks, filling bogs with brush, and making a passable way for the crowd of animals and pack-mules that were to start two or three hours later. How necessary it was to keep the clearing party well ahead of the train will appear when it is known that the pack-train could not stop in the dense forest without great danger of losing some of the animals, as it would be impossible to keep them on the trail; and, once off of it, there was little hope of finding them.

Ont he march, a train of pack-mules travels as a unit,—as though each mule were connected with the one in front,—but let a halt be called, and each one becomes a free and independent creature to hunt for grass, or the bell-mare, at will.

Just before reaching camp, two of the Indians and one of the white guides killed three bears after a lively skirmish. There are wood, water, and grass all along the trail, which is excellent.

Friday, September 5.—The Indian difficulty came up early. The fellow after being told to get ready in time to start with us, went off up the stream to trap for beaver. It was evidently time to deal with him. Calling the one who acted as interpreter, and several of the most prominent Indians about me, I endeavored to make them understand that this fellow was not doing as he had agreed to with me; that we had to travel back to Camp Brown as fast as we possibly could or else our rations would give out, and there was not game enough in the country to feed such a big crowd; that I could go back without his assistance, only it would take longer to find the way, and we might get very hungry before we got back to Camp Brown; that I had sooner do that than have any more nonsense from him, and that he either must do as he had promised, or I would have him tied up and carried back to Camp Brown and put in the white man's jail there. I then sent out two Indian runners to follow up his trail, find him as soon as possible, and tell him that he must come in as fast as he could—well knowing that they would tell him all that I had said. To my utter relief, in about half an hour they were discovered away up the valley returning with him, and driving their horses at desperate speed; without a word he took his place in advance of the column, and soon appeared perfectly cheerful and contented. Still I had a fear that he might in resentment lead us out of the way, and watched him with much apprehension. The few days following proved my fears groundless. He as well as the others were overawed, and said that "the captain" was "heap mad." The only misunderstanding that arose from my talk to them was an impression that I was going to put him and a few of his intimate friends in jail upon our return. We did get into a great deal of trouble on this day's march, but no one worked harder than he to help us out of it.

We broke camp at 8 a. m., and after a march of nine miles the trail led across a large densely-timbered hill. About half way up it the fallen timber lay so thickly across the trail that it soon appeared to be a herculean task to get through it. Everybody took hold, officers, men, guides, and, to the astonishment of all, even the Indians who were with the advance, but before we had any hope of getting through, the train came up with us, making it unnecessary to go into camp.

Sending back word to it to camp before attacking the hill, I sent out the Indians and guides to look up a better place for crossing, and in the mean time scrambled ahead on foot over this trail far enough to see that it would take at least a day to clear away the fallen timber so as to make it practicable.

Toward night the Indians returned, having been successful in finding a way across. They pointed it out to me, and I am free to confess it seemed about as feasible as to lead the train over a squirrel-trail up a tree. It boldly attacked the hill by way of numerous openings at its steepest part.

The trail to camp was good, with wood, water, and grass abundant The vegetation is luxuriant.

All of the Snake River drainage above the Tetons concentrates in a low-lying tract along their eastern base, called Jackson's Hole. For this reason I have called this partial water-shed the Teton Basin.

Viewed from the east, the Tetons rise from a low elevation, and, being projected against a low country, their appearance is truly majestic. From their aspect at this distance, I should judge their structure in altitude to be the same as that at the Washakee Needles, *i. e.*, lamellar granite, forming numerous acicular pinnacles.

Saturday, September 6.—Broke camp at 7 a. m., and making a trail over the tremendously-steep hill by continual zigzags, up which it took the train one hour and a half to climb, we marched ten miles over a very good trail, and camped close by the pass to Wind River.

I rode ahead into the pass with the Indian guide, who pointed to me Wind River Valley displayed at our feet in its full length, with evident pride and satisfaction. Dismounting, I climbed the high mountain south of the pass with much difficulty, and had a view that seemed to unravel a good deal of the mystery in which this region has been wrapped. I found myself on the extreme point of the southwestern angle of the Sierra Shoshonee, and at the very head of Wind River.

Along their southern wall to the southeast lay the Wind River Valley, in which I could see Crow Heart Butte, not far from Camp Brown. Across came the grand Wind River Mountains, sweeping up to a climax in Union Peak and running out at a point ten miles south from me. From just south of this extremity, running west as far as Snake River near the southern extremity of the Tetons, and culminating in snow-clad peaks along the western half, lay a range of mountains which have hardly attracted notice before as such, and which I have named the Wyoming Mountains. From the south they appear as a continuation of the Wind River Mountains. To the west, distant forty miles, the Tetons seemed to pierce the sky with their needle-like spires; between and to the northwest and north lay the Teton Basin, a semi-funnel-shaped region of high, rolling, green-clad hills, narrowing to a focus in Jackson's Hole at the foot of the Tetons, and far beyond was just a glimpse of Mount Sheridan —a grand mountain, which will always do honor to the general's name.

The culminating point of the Tetons has for a very long time been called the Grand Teton. It is a good name, and I see no reason for changing it, although some members of Dr. Hayden's party of 1872 have seen fit to rename it after him. I know of no man who is more worthy of having his name left behind him in the Rocky Mountains than he;

but certainly, among the "thousand peaks worthy of a name" which he describes, along the western face of the Sierra Shoshone, some one might have been selected which would have gone down to posterity with a clearer title.

The Teton Basin is notable for the abundance of its streams, the luxuriance of its vegetation, and the happy distribution of immense areas of low-lying timber-land among a liberal display of grassy slopes and valleys.

Togwotee Pass lies between the head of Wind River and a small tributary of Snake River. It has an altitude of 9,621 feet above the sea, but, notwithstanding this altitude, the approaches to it are quite easy. A railroad could be carried over it without extraordinary expense. Just south of it is the last peak of the Sierra Shoshonee in this direction. It is composed of horizontal layers of volcanic *ejectamenta*, (sand, sandstone, and conglomerate,) and rises to an elevation of 10,625 feet above the sea.

Sunday, September 7.—We crossed the divide and camped on Wind River, after a march of fifteen miles. The trail is good, except about two miles of fallen timber on the Wind River side. After this there is no more timber in the Wind River Valley, except the cottonwood along the streams. Grass occurs in meadows along the streams and sparsely over the rolling hills, on either side.

A marked change of climate is noticeable immediately upon entering Wind River Valley. It is considerably warmer, both by day and night, and the relative humidity is very much less. The effect of this is noticeable in the comparative scarcity of springs, streams, and marshes, in the dry and dusty character of the soil, in the sun-cured grasses, and in the gray and sun-dried appearance of the face of the country so peculiar to the rainless region of the Rocky Mountains. In the Teton and Upper Yellowstone Basin the grasses look fresh and green; there are numberless marshes, springs, and small streams, and the black soil does not fly into a cloud of dust at first touch. Indeed, our whole train rarely broke the soil enough to raise the dust. These considerations, taken in connection with the weather observations made on the trip, lead me to infer that we may find in these basins a region of equable precipitation of rain—a phenomenon of rare occurrence in the great Rocky Mountain plateau. I think it quite probable that here the soil can be cultivated without irrigation; and it may be as well to remark just here that the soil of this great plateau is generally quite rich, however unpromising it may appear at first sight; but in these basins, coming, as it does, from the decomposition of volcanic rocks, it is peculiarly fertile.

Monday, September 8.—Broke camp at 10 a. m., and marched seventeen miles down Wind River. The trail is good and well marked, being the one used by the Indians in their trips to Snake River and Fort Bridger. There is good camping-ground almost anywhere in Wind River. The heat and dust are oppressive.

Tuesday, September 9.—Sent a small party of Indians to Camp Brown to announce our return and obtain information regarding the presence of hostile Indians. Broke camp at 9.45 a. m. and marched twenty miles.

Wednesday, September 10.—Lieutenant Hall and a small party started at 5 a. m. for Camp Brown, expecting to get in before night. Broke camp at 10 a. m., and marched twenty miles to a point about three miles above the mouth of Bull Lake Fork; grass rather thin.

Thursday, September 11.—Broke camp at 9.30 a. m., and crossed Wind River, moving on down to Lake Fork. After crossing the latter we struck across a very high plateau to Sage Creek, coming upon our out-going trail and camping near a former camp. Distance traveled, seventeen miles; grass and poor water; no wood.

Friday, September 12.—Broke camp at 8.30 a. m., and marched eight and one-half miles to Camp Brown.

September 17, 18, *and* 19.—The expedition marched back to Camp Stambaugh, where it was disbanded.

I take the greatest pleasure in according to Captain Noyes the credit that is due him for having, by his skill and energy in assisting us, contributed very largely to whatever of success that has attached to the expedition. Perhaps this will be better understood when I state that a delay of three days at the Big Muddy and Ham's Fork, which might very easily have occurred, would have been followed by a delay of two weeks at Green River on account of the freshet. This delay would have brought us into the Big Horn Valley after the arrival there of a powerful war-party of Sioux, which, it is known, came in shortly after we went out, and who certainly would have driven us back to Camp Brown, and, perhaps, made the expedition a failure.

In conclusion, I may perhaps be pardoned for referring to the opinions that previous explorers have held with regard to the character of the undertaking accomplished by this expedition.

From the report for the year 1872 of N. P. Langford, superintendent of the Yellowstone National Park, I extract the following:

> The park is only accessible from Montana. *It is impossible to enter it from Wyoming.* Attempts to scale the vast ridge of mountains on the eastern and southern borders have been made by several expeditions across the continent, commencing with that of Wilson G. Hunt, the chief of Astor's overland expedition in the year 1811. As late as 1833 the indomitable Captain Bonneville was thwarted in a similar effort, and, after devising various modes of escape from the mountain-labyrinth in which he was lost, determined to make one more effort to ascend the range. Selecting one of the highest peaks, in company with one of his men, Washington Irving says:
>
> "After much toil he reached the summit of a lofty cliff, but it was only to behold gigantic peaks rising all around, and towering far into the snowy regions of the atmosphere. He soon found that he had undertaken a tremendous task; but the pride of man is never more obstinate than when climbing mountains. The ascent was so steep and rugged that he and his companion were frequently obliged to clamber on hands and knees, with their guns slung upon their backs. Frequently exhausted with fatigue and dripping with perspiration, they threw themselves upon the snow, and took handfuls of it to allay their thirst. * * * As they ascended still higher, there were cool breezes that refreshed and braced them; and springing with new ardor to their task, they at length attained the summit.

As late as 1860, Captain Raynolds was foiled in repeated efforts to cross the barrier. While camped on Wind River, at the southeastern base of this formidable mountain, he wrote, (Senate Ex. Doc. No. 77, 40th Congress, 1st session:)

> To our front and upon the right the mountains towered above us to the height of from 3,000 to 5,000 feet in the shape of bold, craggy peaks of basaltic formation, their summits crowned with glistening snow. * * * * *
> Directly across our route lies a basaltic ridge rising not less than 5,000 feet above us, its walls apparently vertical, and no visible pass, or even cañon. On the opposite side of this are the headwaters of the Yellowstone. Bridger remarked triumphantly and forcibly to me upon this spot: "I told you you could not go through. *A bird cannot fly over that without taking a supply of grub along.*" I had no reply to offer, and mentally conceded the accuracy of the information of the "old man of the mountains."

Dr. F. V. Hayden, in his Report for 1871 of the Geological Survey of the Territories, p. 134, says:

> The range of mountains on the east and south of the Yellowstone Basin * * * seems to be entirely of volcanic origin; they are also among the ruggedest and most inaccessible ranges on the continent. From the valley of Wind River they present a nearly vertical wall from 1,500 to 2,000 feet high, which has never been scaled by white man or Indian, but are covered with perpetual snows to a greater or less extent. From any high point a chaotic mass of peaks may be seen.

CHAPTER II.

PHYSICAL GEOGRAPHY.

General description—Green River basin—North Platte basin—Wind-Big-Horn basin—Yellowstone-Teton basin—Indian trails.

The region traversed by this expedition lies in the western extremity of the Territory of Wyoming, including the whole extent of the Territory from the southern to the northern boundary. It lies between N. latitude 41°, along the base of the Uintah Mountains,—a little south of the Union Pacific Railroad,—and 45° at the north boundary of the Yellowstone National Park, and W. longitude 108° at the Big Horn River, and 111° near the western boundary of Yellowstone Park, and the eastern base of the Wahsatch Mountains. It forms a trapezoid, with the longest dimension running north and south, with an area of about 41,925 square miles. Distance across, at the southern boundary, one hundred and fifty-seven miles; at the northern boundary, one hundred and forty-seven miles; and length from south to north about two hundred and seventy-six miles.

It is a portion of the plateau from whose surface rise the numerous ridges which, taken together, form the Rocky Mountains. Between north latitude 41° and 46°, the general trend of these ridges changes from a northerly to a northwesterly direction, and in the obtuse angle thus formed the ridges themselves are so broken and scattered that the eastern water-shed breaks quite through and takes a considerable portion of the drainage from the western slopes, while between them, and extending as far west as the Wahsatch Mountains, in west longitude 111° 30′, the plateau itself is exposed, opening out into the great plains of the Missouri on the east, through the valley of the North Platte River; across the gap between the northern extremity of the Black Hills and the Big Horn Mountains; and on the north through the valley of the Big Horn River between the Sierra Shoshone and the Big Horn Mountains. The Black Hills of Dakota form a remarkable outlier nearly opposite the eastern opening and the point of the angle—lying between the two main forks of the Big Cheyenne River, a tributary of the Missouri, in latitude 43° north and longitude 109° 30′ west from Greenwich.

Hypsometrical observations enough have now been taken by the numerous parties that have traversed it, to show a fair approximation to the mean height of this plateau above the sea, but they are not available for my reference, as this writing is done at a place where the necessary means of reference upon scientific subjects are very scant indeed. Enough has come within my observation, however, to lead me to estimate it at about 6,500 feet.

Its breadth from east to west along the parallel of 42° north latitude is three hundred and nine miles, and its length along the meridian of 108° 30′ is three hundred and forty-five miles. The area described is, as a rule, semi-barren and treeless, although the soil is quite rich and supports a scanty growth of extremely nutritious grass in connection with a few very hardy shrubs.

The line of the Rocky Mountain divide, or water-parting, passes through this region. This line, after traversing the country from Mexico in a northerly direction between the meridians of 106° and 108° west longitude, is deflected from its course in north latitude 40° 30′, where bending around the head of North Park it soon leaves the ridge of maximum elevation—in fact leaves the mountains altogether—and, taking a northwest-by-northerly trend, follows a low line at an elevation of about 7,500 feet across the plateau just described to the Wind River range, making a sharp detour about the head of the Sweetwater River, which here breaks through the low ridge and intrudes upon the Pacific water-shed, giving a poor excuse for the name of South Pass; thence following the summit of the range to its northwestern extremity; thence by a tortuous course about the heads of the Wind, Snake, and Yellowstone Rivers in the Sierra Shoshone range, from which it shortly emerges into the Yellowstone Lake Basin; thence northwesterly, skirting the southern border of Yellowstone Lake, at an altitude, in some places, of between two and three hundred feet above it, running—still a very tortuous line,—between Shoshone Lake and the Upper Geyser Basin, on Fire-Hole River, to the low ridge, with a deep flexure to the southeast, which surrounds the sources of the Three Forks of the Missouri; thence returning to the line of direction departed from it takes a north-northwesterly course into the British Possessions. It will be seen that for the greater portion of this distance the continental divide is a comparatively low line, with high mountain-ridges arranged on either side of it, on the opposite slopes of the great plateau.

Including the portion of this divide between the parallels of 44° and 51° north latitude, we have the crown of the water-shed of the continent, from which the water is shed literally in all directions, as from a point; to the north through the Mackenzie River, to the Arctic Ocean; to the east, through the Saskatchewan and Lake Winnipeg, to Hudson's Bay; to the east and south, through the Missouri, Yellowstone, Wind, and Big Horn, to the Atlantic Ocean; to the south, through the Green and Colorado, to the Gulf of California and the Pacific Ocean; and to the west, through the Snake and Columbia, to the Pacific.

The table-land of Wyoming, previously described, forms, in the southern half, the most important pass through the Rocky Mountain chain. It is a belt about one hundred and forty miles broad, from north to south, and is traversed by roads along its northern and southern borders and through the middle, the latter being the line of the Union Pacific Railroad.

The principal water-sheds formed are five, viz: 1st. The Mackenzie-Saskatchewan; 2d. The Missouri-Mississippi; 3d. The Colorado-Snake; 4th. The Columbia; and 5th the remarkable region lying between north latitude 33° and 43° and west longitude 111° and 121°, where the surface-waters are either carried into lakes without outlets or into "sinks," where they disappear from the surface. To give a description of these water-sheds would lead me beyond the scope of this paper into a field for which sufficient material for reference is not available. The description will, therefore, be confined to the subordinate basins lying near their superior limits and within the field of the reconnaissance. These are the Green River, the North Platte, the Wind River, the Big Horn, the Upper Yellowstone, and the Teton Basins.

THE GREEN RIVER BASIN.

This basin is formed by the Wyoming and Wind River Mountains and the continental divide on the north and east, and by the Wahsatch and Uintah Mountains on the west and south. Its dimensions are two hundred and twenty-three and one hundred and seventy-five miles along the forty-first parallel and the one hundred and tenth meridian, respectively.

The Wyoming Mountains form a spur, which leaves the Wind River range near Union Peak, in latitude 43° 25′, longitude 108° 50′, running in a westerly direction to Snake River. The highest elevation is Mount Leidy, near the western extremity. Near their junction with the main range the altitude becomes quite low, forming one of the passes through which the Shoshonee (Snake) Indians reach the head of Green River. The Wind River Mountains rise from the continental divide, in latitude 42° 30′, longitude 108° 48′, at Camp Stambaugh, and run, with a north-northwesterly trend, at an elevation of about 13,000 feet, to latitude 40° 37′, longitude 109° 55′. The culminating points are: (1) Union Peak, near the northwestern extremity, with an estimated altitude of 14,000 feet; and (2) Fremont's Peak, near the southeastern extremity, whose altitude is 13,750 feet. This range is one of the principal elevations in the Rocky Mountains. It is a huge ridge, with the sedimentary rocks sweeping up in long, broken slopes to a broad belt of crystalline schists at the summit. This belt is estimated to be about eight miles broad, and is very much cut up by fissures. Numerous veins of quartz occur in it. The Sweetwater mines are found in these rocks, on the southwestern extremity of the ridge.

Along the northern slope deep monoclinal valleys occur, from which the waters escape to the plains below through short, but very sharp and deep, cañons. Only a few of these openings occur, and between them the long, smooth slopes have suffered comparatively little from erosion, and are probably seen now in something like the original shape. The principal valleys are longitudinal, and not transverse, as is usually the case. Considerable timber occurs, but it is in the valleys above the lower ridges.

There is a pass across to the head of Green River, near Union Peak, and another across to the Gros Ventres Fork of Snake River. Animals have been ridden across from the head of Green River to Camp Brown, but it is probably quite a difficult task.

The continental divide is simply the line of superior elevation of the plateau itself. Its altitude is about 7,500 feet; but little above the surrounding country. South Pass is where the Sweetwater breaks through, and does not deserve the name of pass at all.

The Wahsatch range in Northern Utah has a trend that bears a little west from north; toward the southern extremity the direction of the range seems to bear off considerably to the west, but I surmise from a hasty personal examination that this is caused by a number of the parallel ridges, so characteristic in Utah, lapping over each other thus:

The range comprises a series of three or more parallel ridges, which terminate in about latitude 43°, although it is probable that the Tetons, much farther north, really belong to it. Its southern limit has not been very well defined yet, but it will not be far wrong to place it in latitude 37°. In Northern Utah the peaks are generally from 10,000 to 12,000 feet high, the latter limit being reached in the Twin Peaks, a little southeast from Salt Lake City. The range is not more than fairly timbered.

The Uintahs are considered a spur from the Wahsatch, but it is more probable that they are one of the transverse ridges of the Rocky Mountain chain. Their elevation is considerably greater than the Wahsatch. They leave the latter in the vicinity of latitude 40° 30′, thence trending northwesterly by a curved line, which turns a little to the south before reaching Green River, where it practically terminates. The extreme elevation is attained in the vicinity of Gilbert's Peak, where Mount Hodges and Mount Tòh-kwana have an elevation of about 13,500 feet. Gilbert's Peak is 13,250 feet. The range forms an immense ridge, with an almost level but badly-broken-up ridge on top, having a width of from twenty-five to thirty miles, and an altitude of about 6,000 feet above the table-land on the north, and about 7,000 feet above the similar table-land on the south.

The valleys are numerous, deep, and narrow, except at the head, and extend quite up to the summit. Between them, on the north, are the transverse and generally unbroken ridges, by means of which the summit can be reached by a gradual ascent. On the south these ridges are badly broken toward the summit. Ranged on either side of the summit-line are enormous basins of erosion at the head of the valleys. They have a direction considerably oblique to that of the prevailing winds, and in consequence the amount of snow that drifts in during the winter must be enormous. At such an altitude this snow melts comparatively slowly and furnishes an almost continuous supply of water to the very numerous mountain-streams, much of which is first caught in the multitude of small lakes that are sprinkled around the border of the basins. On the north slope there is a good deal of marsh in these basins, but on the south the water, having to make about 1,000 feet more descent in reaching the plains, runs off much more rapidly, and leaves but little marsh. This circumstance, combined with the greater heat of the southern exposure, makes many of the smaller streams run dry early in the season.

The opposite valleys frequently start from about the same point and have between their sources only a thin precipitous wall, which erosion is slowly removing. Gilbert's Pass, at an elevation of 11,000 feet, is such a point. Here the wall has been sufficiently worn away to admit of the construction of a road across it. There are probably few such places at present. The broad belt or strip along the summit is broken and eroded enormously; ridges of high peaks extend across it between the valleys, and many narrow precipitous cañons occur, both along the valleys and transversely to them. The sides of these ridges are generally masses of broken rock. The country along the base of the mountains, both on the north and south, is an elevated, highly-terraced plateau of soft earth, the slopes of the terraces being generally as steep as the earth will stand, and frequently quite barren.

The timber-line, or superior limit of forest-growth, is at an altitude of 11,000 feet. Below this these mountains are covered with a dense forest, very much interspersed with small openings of meadow.

Of the northwestern outline of this basin comparatively little is known. It is probable that the divide here between Green and Snake Rivers is a low ridge of mountains—a continuation of the Wahsatch system.

Of the mountain-ranges described, none rise to the limit of perpetual snow. Only a few large banks or drifts on their northern slopes remain from one winter to another.

The basin itself is a broad highly-terraced plain, the bed of an ancient lake. Away from the immediate vicinity of its scanty streams the excessive erosion of the soft soil has left many isolated buttes and patches of bad lands, and there is everywhere the appearance of barrenness given by the gray hue of the universal sage-brush and grease-wood. The soil, however, as a general rule, is quite rich, and produces splendid crops where sufficient water can be supplied to it by irrigation, and when the unseasonable frosts do not interfere. Bunch-grass, which is extremely nutritious, grows sparsely among the sage-brush.

The water comes entirely from the surrounding mountains, springs being very rare indeed. Some very fine springs occur near South Pass; at Pacific Springs.

The valleys of the streams are narrow, with meadow and pasturage near the mountains, but toward the interior the vegetation is rather sparse. No trees grow except a few cottonwoods along the streams, and away from the mountains even these are rare. The region is infested with great swarms of grasshoppers. In and near the mountains the valleys are fertile, well watered, and, together with the lower slopes, furnish an extensive and abundant pasturage. Some rain falls, but probably not sufficient for cultivation of the soil without irrigation.

All of the hardy cereals and vegetables can be successfully cultivated both in the mountains and on the plains.

In the mountains extensive forests of coniferous trees occur, but as the streams are generally not large enough to float logs, they are, or rather will be, for some time inaccessible.

The rivers are Green River and its tributaries. Green River rises in the southwestern slopes of the Wind River Mountains and southern slopes of the Wyoming Mountains. Its course through the basin is generally southerly until it strikes the base of the Uintah Mountains, where its course is deflected to the left in seeking for a passage through them in longitude 108° 53′. It receives numerous tributaries from the outliers of the Wahsatch on the right, and, with the exception of Bear River, the whole drainage from the north slopes of the Uintahs, and a few on the left from the continental divide.

Of those on the right the principal ones are: (1) Black's Fork, which drains the angle between the Wahsatch and the Uintahs; and (2) Henry's Fork, which drains the middle slopes of the Uintahs. On the left we have: (1) The Big Sandy with its tributaries draining the southern slopes of the Wind River range and a short portion of the continental divide; (2) Bitter Creek, which rises in the continental divide and traverses a country where the soil generally carries a considerable quantity of alkaline salts, giving their character to the few streams that flow through it; and (3) the Little Snake River, which drains that portion of the continental divide which lies south of the Union Pacific Railroad.

THE NORTH PLATTE BASIN.

This region is bounded on the south and west by the continental divide and the southeast extremity of the Wind River range; on the north by the low divide that separates the Sweetwater and North Platte Rivers from the Wind and Powder Rivers; on the east by the Black Hills. Its greatest dimensions are 204 miles along the parallel of 42° 30′, and 173 miles along the meridian of 106° 30′.

The Black Hills form the continuation of the easternmost ridge of the Rocky Mountains beyond the point where the line of general direction of the range is deflected to the northwest. Their northern limit is near Laramie Peak, in latitude 42° 10′ and longitude 105° 25′; from this point their direction is almost due south to latitude 41°, where the Cache-la-Poudre, a tributary of the South Platte, breaks through the ridge. The general altitude is between 8,000 and 9,000 feet. It is a low range with gently rounded slopes, and a ridge of granite crags along the summit, culminating in Laramie Peak, one of the noted landmarks of the West. The western slopes, running down into a tableland whose elevation is about 7,000 feet, are much shorter than the eastern, which leave the plains at an altitude of 6,000 feet—1,000 feet lower. The axis-line lies quite close to their western border. But little water is drained from their western slopes, while the eastern is quite well watered, furnishing many fine valleys susceptible of cultivation. There is good grazing all over the range. Timber occurs, but somewhat sparsely. The ridge is crossed by numerous roads.

The Medicine Bow Mountains are the continuation of another ridge of the Rocky Mountain chain in Colorado, which extends as an isolated ridge into the basin of the North Platte, between the Black Hills and the continental divide. This high range has its northern limit near Elk Mountain, in latitude 41° 40′, longitude 106° 30′. From this point the range has a southeasterly trend to its southern extremity, which is imperfectly known, and indeed but little is known of the range itself.

The basin has very nearly the same surface characteristics as the Green River Basin. Whether the ancient lake that once occupied the latter extended across the divide into this, to cut it up into terraces during its subsidence, is still an unsettled question. This much is certain, that the country is smoother and not characterized by terraces to anything like the extent of the former.

The Laramie plains is a bight of land extending in a southerly direction between the Black Hills and the Medicine Bow Mountains. This is the most favored spot in the whole plateau; the surface of the country is rolling, and thinly covered with grass, while the valleys of the streams through it afford excellent pasturage. Irrigation is necessary in the cultivation of the soil. Quite a noticeable feature of the whole plateau is that grazing is possible during the whole year; and although but little rain falls, yet the grasses become sun-cured, and are always very nutritious. The North Platte River rises in North Park, an elevated valley of the Rocky Mountains, in latitude 40° 30′, longitude 106°, and flows in a northwesterly direction, carrying the drainage of the Medicine Bow range and the continental divide, to latitude 41° 30′, where it bends to the north—passing the Union Pacific Railroad at Fort Steele, as far as latitude 42° 20′, when it enters a deep cañon of inconsiderable length, and, sweeping around in a semicircle to the east and south, marks out, perhaps, the northern limit of the easternmost ridges of the Rocky Mountain chain.

On the right its principal tributaries are: (1) Medicine Bow River, which drains the north slopes of the range of that name and the south slope of the hills in the great bend of the river; and (2) the Laramie River, which drains the eastern slopes of the Medicine Bow Mountains and the slopes in the angle between the latter and the Rocky Mountain range, and flowing northerly through the Laramie plains makes a short bend to the eastward, in latitude 42°, cutting a cañon quite through the Black Hills, and joins the North Platte in latitude 42° 12′, at Fort Laramie. On the left its only tributary of importance is the Sweetwater River, which takes its rise in the southern slopes of the Wind River Mountains and flowing in an easterly direction joins the North Platte in latitude 42° 25′.

The roads that cross the two basins just described in the direction of the parallels of latitude have already been mentioned. They are also traversed by—(1) a road from Medicine Bow Station, on the Union Pacific Railroad, in a northerly direction to Fort Fetterman; (2) one from Point of Rocks, on the railroad, northward to South Pass City and the Wind River Valley; (3) one from Bryan, on the railroad, northeasterly to the Sweetwater mines and Wind River Valley; (4) one from Fort Bridger to South Pass in a northeasterly direction, (the old emigrant-road to Salt Lake City and the Pacific coast;) and (5) one from Evanston, on the railroad, northward along the valley of Bear River to the Mormon settlements at Bear Lake to Soda Springs, and to Fort Hall, in the Snake River Valley.

THE WIND-BIG HORN BASIN.

This basin opens into the basin of the Lower Yellowstone on the north; has the Big Horn Mountain on the east, the low divide between the Sweetwater and the Wind-Big Horn on the south, and the Sierra Shoshone and Wind River ranges on the west. Its longest dimensions are one hundred and seventy-five miles along the meridian of 108° 30′, and one hundred and twenty-six miles along the parallel of 43° 30′.

Of the Big Horn range but little that is reliable is known. The probability is that the axis is a curved line. Commencing very low, about in latitude 43°, longitude 107° 30′, the line of direction runs northeasterly as far as Cloud Peak, the summit of the range in latitude 44° 23′, longitude 107°, and thence northwesterly to the Big Horn River in latitude 45° 10′, longitude 108° 7′. The culmination seems to be a cluster of peaks. To the north of these the range sinks to a low elevation, where the summit has something of the character of a plateau, and to the south also the elevation seems to be quite low. The streams that flow from their eastern slopes are very numerous and water a fine country along their base, while from the western slopes scarcely a stream flows that is worthy of the name, and the bordering country is a barren waste.

The Sierra Shoshonee range sends off a light spur, half-way across the basin, in the Owl Creek Mountains, whose line of direction is about south 27° east from latitude 43° 40′, longitude 109° 10′, from whence they run with an average elevation of about 8,250 feet as far as the Big Horn River, attaining a maximum elevation of 9,136 feet in Phlox Mountain. The foot-hills on the south are much more rugged than the mountains themselves, showing many sharp ridges where the rocks are tilted vertically, apparently in two directions, one parallel to the range and the other making an approach to a right angle with it. Above these, and on the north, the slopes are smoothly rounded and support a fine growth of grass and sparse groves of aspen, hemlock, spruce, and pine. The summit is formed by ledges of the sedimentary rocks, arranged, in a measure, alternately along the opposite sides of the axis-line.

The amount of water that is shed from the south slopes is extremely small, while the north slopes are comparatively well watered. A strange freak occurs at the western extremity of the range, where Owl Creek, after taking its rise at the Washakee Needles, cuts through to the anticlinal axis of the Owl Creek range, which it follows for quite a distance through a wild precipitous cañon, from whence it emerges into the plains seemingly from a source in this range, whereas its source is really in the Sierra Shoshonee Range. The Sierra Shoshonee range is probably the most remarkable one in the great Rocky Mountain chain. The original range, if there ever was one, and of this there are many indications, lies buried beneath an outpouring of material from the fluid interior of the earth, which it is safe to estimate as being now from 4,000 to 5,000 feet thick. This statement is warranted by the fact that the section cut through by the Stinking Water River shows only this volcanic material down to an elevation of 5,500 feet, while the peaks are all over 10,000 feet, and many reach an elevation of over 12,000 feet, and are composed entirely, so far as our observation went, of this material, (except the Washakee Needles, which is granite.) It will be more appropriate to speak of it as a mountain mass, which extends from latitude 43° 10′ in a northerly direction, to 45° 10′, with a general width of over sixty miles in peaks that will certainly average over 10,000 feet in elevation. The culminating points are at the Washakee Needles, near the southeastern extremity, where the elevation is 12,253 feet, and in a cluster of peaks, in latitude 45°, whose elevation is not known. Between these, however, there are probably quite a number of summits that equal and, perhaps, exceed them in elevation.

It is doubtful whether any of the craters, from which this enormous mass of once-fluid material escaped, have yet been discovered. There are many appearances of volcanic cones, but a close examination will probably show them to be simply peaks of erosion. This mountain mass has been eroded to a remarkable extent, and the streams have cut their channel into it accordingly in the most irregular manner. The Snake cuts clear through from the west to the east side, and the Grey Bull and Stinking Water on the east have their sources in the very westernmost rim. Their valleys are simply huge cañons, except the usual park-like opening near their sources.

The mountain-slopes are covered with forests of coniferous trees, wherever it is possible for trees to grow, and streams are very numerous. Perhaps more water is shed from this mass of mountains than from any of equal size in the Rocky Mountain chain.

There are no roads across the Sierra Shoshone range, and this expedition is the first that ever crossed it, a feat that had been previously considered very difficult, if not impossible. Three passes were found across: one along the Ishawooa River to the head of Yellowstone Lake; one by the North Fork of the Stinking Water to the foot of Yellowstone Lake; and one from the head of Clark's Fork to the East Fork of the Yellowstone.

The basin is divisible into, 1, the Wind River Basin; and 2, the Big Horn Basin.

1. The former is triangular in shape and traversed by the Wind River and its tributaries. It is characterized by high benches, dropping off by steep slopes to the river. Along the right bank of the river, as far down as Bull Lake Fork, a great deal of bowlder drift occurs, and the soil, away from the narrow bottoms along the streams, is quite rocky. On the left bank there is not so much of this drift-soil, and it disappears below Crow Heart Butte, a noted landmark in the valley, which seems to have been left to point toward the amount of erosion that has taken place. The favored portion of the valley is along the foot of the Wind River Mountains, in the region watered by Wind River, below Crow Heart Butte, Little Wind River, and the Popo-agies. The mountain-slopes are clothed with grass, and the valleys of these streams are quite fertile and lie well for irrigation. North of Wind River the country is generally rather barren.

2. The Big Horn Basin is generally barren, except the narrow belts along the streams, the foot-hills of the Sierra Shoshonee and Owl Creek Mountains, and the strip of country along the base of these mountains, which is tolerably well watered, fertile, and clothed with grass. Except along the streams, but little timber occurs. The general aspect of the country is rugged, parched, and barren.

The Wind-Big Horn River rises in the angle between the Sierra Shoshone and the Wind River Mountains, in latitude 43° 40′, longitude 110°, and, with the name of Wind River, runs in a southwesterly direction for nearly the length of the Wind River Mountains, whence, rounding to the northward, making the "big bend," it proceeds northerly to its cañon through the Owl Creek Mountains; here it loses its first name and is called, thenceforth, the Big Horn River, which flows northerly to its cañon through the extremity of the Big Horn Mountains, and thence to its junction with the Lower Yellowstone. The name "Big

Horn" comes from the Indian name for the mountain-sheep, which are quite numerous in the mountains about this basin. The Indians call them "big horns." It was the custom of early trappers to name localities from such circumstances as the abundance of certain kinds of game, trees, &c., in their vicinity. The principal tributaries, on the right, are Campbell's Fork, Bull Lake Fork, Little Wind River and its tributaries, the two Popo-agies and Beaver Creek from the Wind River Mountains, and Bad Water Creek and No Wood Creek from the Big Horn Mountains. On the left, De Noir Fork, North Fork, and Dry Fork, from the south slope of the Sierra Shoshonees; Muddy Creek from the south slopes of the Owl Creek Mountains, and Owl Creek, Meeyer-o Creek, Gooseberry Creek, Grey Bull River, and Stinking Water River, from the Sierra Shoshonee.

A wagon-road, opened by James Bridger, leaves the old North Platte road from Fort Laramie near Red Buttes, follows up Poison Spring Creek, and thence across to the Big Horn River, which it follows up a short distance and then strikes across the basin to Heart Mountain, from whence it proceeds in a northwesterly direction to the settlements in Montana. It traverses a very barren country, in which good water is very scarce for a considerable portion of the distance.

THE YELLOWSTONE-TETON BASIN.

As the region here to be described is quite small, it is thought advisable to treat it as a whole, although it is traversed by the main divide of the Rocky Mountains—here very low—and part of the divide between the Upper Yellowstone and Missouri Rivers. It includes the Yellowstone National Park. It has the Sierra Shoshonee range on the north and east, the Wyoming Mountains on the south, and the Tetons on the southwest. All but the latter have been described. This range is quite short, and extends in a northerly direction between the parallels of 43° 30′ and 44° 15′, in longitude 110° 35′. A few peaks are quite acicular in character, and attain in the Grand Teton and Mount Moran the altitude of 13,835 and 12,800 feet respectively, as given by Professor Hayden. The figures are largely in excess of what the previous estimates of these altitudes had been. This region is an elevated plateau, lying about the sources of some of the principal rivers of the continent. It has a surface of high, rolling hills, covered with dense forests, with many lakes, some quite large, about the sources of the streams which lower down have cut very deep valleys.

The northwestern portion about the sources of the Gallatin and Madison is mountainous, culminating in Mount Washburn, overlooking the Grand Cañon of the Yellowstone at an elevation of 10,105 feet. About 10 miles south of Yellowstone Lake is Mount Sheridan, a small knob, with an elevation of 10,156 feet. The soil is quite rich, and vegetation flourishes, although there are indications of a severe climate. At the foot of the Tetons, on the east, is a large, fertile valley called Jackson's Hole. In the midst of it is Jackson's Lake, a considerable body of water. The whole region is thoroughly well watered and is notable for the quantity of timber which it carries on low-lying land. Its greatest dimension is one hundred and four miles from north to south, and there is an area of over five thousand square miles. Southwest from Yellowstone Lake is a cluster of small lakes—of which the largest is Shoshonee Lake—all at the sources of Snake River.

Yellowstone River rises in the Sierra Shoshonee range about fifty miles above the lake, to which it flows in a northwesterly direction.

Shortly after leaving the latter it makes a fall of about 500 feet into its Grand Cañon, through which it flows in a curved line, emerging with a northwesterly direction, and afterward makes a grand detour around the northern extremity of the Sierra Shoshonee, from whence it joins the Missouri by an easterly and northeasterly course.

Within the limits of the region described, the only tributaries of consequence are Pelican Creek and East Fork, on the right, flowing from the Sierra Shoshonee.

Snake River rises along the Continental divide, between latitude 43° 50′ and 44° 30′, in a large number of streams that spread out like a fan from a base at the foot of the Teton Mountains. The principal ones are: 1st, Lewis Fork, rising in a series of lakes lying southwest from Yellowstone Lake; 2d, Barlow's Fork, a tributary of the latter from the east; 3d, Pacific Creek, rising near Two-Ocean Pass; 4th, Buffalo Fork, rising far to the eastward, in the vicinity of the Washakee Needles; and 5th, Gros Ventres Creek, rising near the head of Wind River.

There are no roads traversing this basin. One from Fort Ellis leads to the Great Hot Springs, just inside of its northern limit.

INDIAN TRAILS.

The following are some of the important Indian trails traversing the region visited by the expedition:

1. From Camp Brown, up Wind River Valley nearly to its head, and across the divide to the Gros Ventres Fork of Snake River. Here it forks, sending one branch down the stream as far as Jackson's Hole, where it forks in turn, one portion leading down the Snake River to Fort Hall, and the other, bending sharp around to the northeast, follows up Pacific and down Atlantic Creeks to the Yellowstone River, down which it follows, passing, to the east of Yellowstone Lake, to the Crow country in Montana—a branch of it following Lewis Fork and the west side of the lake and river; the other branch leaves the Gros Ventres near its head, and, bending to the south, crosses a low pass in the Wyoming Mountains to the headwaters of Green River, which it follows down to the open country and thence to Fort Bridger.

2. From Camp Brown to the North Fork of Wind River, which is followed up, and two divides—one to the headwaters of Snake River—crossed to reach the headwaters of Yellowstone River, which is followed down to Yellowstone Lake, where it joins the trail previously described. The divides crossed are extremely difficult.

3. From the "big bend" of Wind River along the left bank to Dry Fork, which is followed up to its head, and a low divide crossed to the headwaters of Owl Creek near the Washakee Needles, whence it passes up this stream to its source, passing through a remarkably fine hunting-ground for mountain-sheep. There is here one of those luxurious mountain-parks which Nature seems occasionally to throw off in the very midst of her most forbidding works. Its existence would never be suspected from without, as there is about it nothing but the most desolate and forbidding scenery, while Owl Creek, the natural approach, after leaving it, flows for a long distance through a tremendous cañon along the very axis of the Owl Creek Mountains, from whence it emerges into the plains, seemingly from a source near their summit; a higher source would scarcely be suspected. This park bears many evidences of having been used as a hiding-place. Our Indians knew nothing of it, and yet there are all through it numerous trails, old lodge-poles, bleached

bones of game, and old camps of Cheyennes and Arapahoes. We may expect to hear from it some day as a hiding-place for horse-thieves and other marauders.

4. From Camp Brown northward over the Owl Creek Mountains, and still further north to the buffalo-grounds of the Big Horn Valley and the Stinking Water River, near Heart Mountain, thence up the North Fork of that river and over the divide to the trail along Yellowstone Lake.

5. From the "big bend" of Wind River eastward along the northern face of the Sweetwater Valley, by the head of Powder River to the Sioux country east of the Big Horn Mountains.

6. From the "big bend" of Wind River northerly into the Big Horn Valley.

7. From Camp Brown to the head of Wind River, thence through Togwotee Pass, and northerly across the drainage of Snake River, striking at Pacific Creek, a previously-described trail from the Tetons to the east side of Yellowstone Lake.

8. From the Wind River Valley across the Wind River Mountains, above Union Peak, to the headwaters of Green River.

CHAPTER III.

THE YELLOWSTONE ROUTE TO MONTANA.

A short route to the Yellowstone National Park.

The discovery of Togwotee Pass, at the head of Wind River, is pregnant with results to the future commerce of the West and Northwest, as it discloses in all probability one of the principal highways that will in the future bind their interests with those of the Mississippi Valley and the Atlantic States.

One important object of the expedition was to discover, if possible, a practicable approach to Yellowstone Lake from the south or southeast, an approach which would not only furnish the shortest route to the Yellowstone National Park, now practically inaccessible, but would open a new route to Montana by a wagon-road but little, if any, longer than the present one from Corinne, Utah, that would save a considerable distance by rail. In this it has met with a gratifying success.

In the first place, it was ascertained that there are three passes through the Sierra Shoshonee affording approaches to the Yellowstone Basin from the east. These are: 1st, from the head of Clark's Fork to the East Fork of the Yellowstone; 2d, from the head of the North Fork of the "Stinking Water, entering the basin opposite the foot of Yellowstone Lake, (the route of the expedition;) 3d, from the head of the Ishawooa River, entering the basin opposite the head of Yellowstone Lake. These passes aer all difficult.

Also one at the head of Wind River, a little southeast from Yellowstone Lake, which affords a perfectly *practicable passage to the Yellowstone Valley, via Wind River Valley and the head of Wind River.* I have named it Togwotee Pass, preferring to attach easy Indian names, wherever possible, to the prominent features of the country. It lies in latitude 43° 46′ 29″, longitude 110° 1′, and has an altitude of 9,621 feet above the sea. Notwithstanding this altitude the slopes approaching the summit so long and regular that a railroad could be built over it at a reasonable cost.

At present there are two routes to Montana, over which the interchange of products between that Territory and the East is carried on, and government supplies shipped to the military posts and the Indians in that country. These are: 1st, the Missouri River route, by which supplies are carried by steamboat as far as Fort Benton, Montana, and from thence distributed through the Territory by wagons; and, 2d, the Union Pacific Railroad route, over which supplies are carried by rail as far as Corinne, Utah, and from thence northward, by wagons, to Idaho and Montana. In the Government's freighting contracts of 1873, the rates from Fort Benton to points in the Territory, and from Corinne to the same points, are exactly the same. Of course, so far as *rates* are concerned, the land-route cannot compete with the water-route; but the river-route is only open during a few months of the year, and during the remainder of the time the land-route is not brought into competition with it. Furthermore, during the season that the river is open, its navigability is far from being certain and reliable at all times; so that shipments over it are detained a very long and wholly uncertain length of time *in transitu*. As the business of the country is now conducted, men can ill afford to have their money lying idle for months, or weeks, or even days, locked up in goods *in transitu*. Every day saved on goods, of *whatever character*, is the equivalent of money gained. It is this element of *time and its money equivalent* that underlies the astounding success of railroads as competitors with water-lines of traffic—success through which the steamboat is disappearing from our rivers; success that is proving to us that there is no such thing as slow freight; that men want some kinds of freight shipped *faster* than others, but that there is none they want shipped in a slow and unreliable manner.

These considerations are so potent that, were a railroad constructed to Montana from some point on the Union Pacific Railroad, it would, in all probability, be followed by virtual disappearance of steamboat-traffic from the Missouri River; and it is by no means improbable that the great saving in distance effected by the new Yellowstone route will, even without any more railroad, enable the land-route to compete successfully with that *via* the Missouri. In all events, the proposed route is fraught with benefit to the people of Montana, through the bringing of the rival lines into a closer competition.

The present land-route leaves the Central Pacific Railroad at Corinne, Utah, and runs in a northerly direction through Idaho to Montana, crossing the Bannack Mountains on the divide between the Snake and Missouri Rivers. The distance from Corinne to Fort Ellis, Montana, is four hundred and three miles. The proposed road should leave the Union Pacific Railroad in the vicinity of Point of Rocks, Wyoming, and run about north into the Wind River Valley; thence following up that valley to its head, and through Togwotee Pass, northerly, to Yellowstone Lake, and through the Yellowstone National Park to Fort Ellis. This route would pass directly by all of the principal phenomena of the park—except the geysers, which could easily be reached by a short side-road. By it, the distance from Point of Rocks to Yellowstone Lake is two hundred and eighty-nine miles, and to Fort Ellis four hundred and thirty-seven miles.

COMPARATIVE TABLE OF DISTANCES.

Omaha, Neb., to Corinne, Utah	1,055	miles.
Omaha, Neb., to Point of Rocks, Wyo	805	"
Distance saved by rail	250	"

Omaha, Neb., to Yellowstone Lake.

Omaha to Corinne	1,055 miles.	
Corinne to Fort Ellis, Mont	403 "	
Fort Ellis to Yellowstone Lake	118 "	
Omaha to Yellowstone Lake, (present route)		1,576 miles.
Omaha to Point of Rocks	805 "	
Point of Rocks to Yellowstone Lake	289 "	
Omaha to Yellowstone Lake, (proposed route)		1,094 "
Proposed route shortens distance to Yellowstone Lake		482 "

Omaha, Neb., to Fort Ellis and Bozeman, Mont.

Omaha to Corinne	1,055 miles.	
Corinne to Fort Ellis	403 "	
Omaha to Fort Ellis, (present route)		1,458 miles.
Omaha to Point of Rocks	805 "	
Point of Rocks to Fort Ellis	437 "	
Omaha to Fort Ellis, (proposed route)		1,242 "
Proposed route shortens distance to Fort Ellis		216 "

It is fair to presume that the freight and passenger rates will be about the same over the proposed as they are over the present route, as the distances are nearly the same. A reasonable comparison between these rates can therefore be made from the following table, showing those paid by the Government to the Union Pacific Railroad.

TABLE OF RATES.

Transportation of persons—(amount for each person.)

Omaha to Corinne	$79 25
Omaha to Point of Rocks	57 25
Amount per man saved by the proposed route	22 00

TRANSPORTATION OF FREIGHT.—THIRD CLASS.*

(4 cents per ton per mile.)

Omaha to Corinne, (1,055 miles,) per ton	$42 20
Omaha to Point of Rocks, (805 miles,) per ton	32 20
Amount per ton saved by the proposed route	10 00

SHIPMENTS OF FREIGHT TO MONTANA.

Shipments to Montana via Union Pacific Railroad.

Years.	Amount.
1869	1,125,960 pounds.
1870	6,896,723 pounds
1871	7,501,280 pounds.
1872	6,129,644 pounds.
1873	(about) 6,000,000 pounds.

Shipments from Saint Louis to Montana, via all routes

Years.	Amount.
1871	13,000,000 pounds.
1872	10,000,000 pounds.
1873	6,000,000 pounds.

* Based upon present rates of Union Pacific Railroad from Omaha to Ogden.

The proposed route will not be blocked by snow so much as the present one, as the snow-belt lies in a heavily-timbered country, in which the snow will not drift much. This will include a distance of fully one hundred and fifty miles north from Wind River Valley. It will open up a body of 2,000,000 acres of timber-land, well watered, and with a rich soil. Observations thus far indicate that this is a region of equable precipitation of rain, and that irrigation will not be necessary in cultivating the soil. There is considerable frost even during the summer, but in spite of it the vegetation is always quite luxuriant.

There is good reason for believing that the Yellowstone National Park will, in time, become the most popular summer-resort in the country, perhaps the world. This, of itself, is a sufficient reason for opening the way to it at once.

To sum up, the proposed route will save two hundred and fifty miles of distance by railroad; four hundred and eighty-two miles in reaching Yellowstone Lake, and two hundred and sixteen miles in reaching the principal cities of Montana; is a direct route to the Yellowstone National Park, which at present is practically inaccessible, and will eventually be the shortest railroad line to Montana; it opens up a very large tract of low-lying timber-land, a feature of rare occurrence in the great Rocky Mountain plateau; it will open up to settlement the Wind River Valley, the Teton Basin, and the valley of the Upper Yellowstone; and, finally, will throw open the Yellowstone National Park to the wonder-seekers of the world.

CHAPTER IV.

METEOROLOGY.

Instruments—Climate of Green River, Big Horn, and Yellowstone—Teton basins—Probable region of equable precipitation of rain—Table of altitudes—Table of weather-observations.

Observations were taken with barometers, (two cistern and three small aneroids,) thermometers, hygrometer, maximum and minimum thermometers, and solar and terrestrial radiation-thermometers. In all possible cases, the temperature of springs, including thermal springs, was taken. The temperature of the latter will be treated in the report of Dr. C. L. Heizmann, assistant-surgeon U. S. A. Observations were generally taken by Mr. J. D. Putnam, under the direction of Dr. C. C. Parry, and are, in my opinion, thoroughly reliable. Mr. Putnam deserves special mention for having carried cistern-barometer No. 1972 (Green) the round trip, frequently in very difficult mountain climbing and marching, without getting it injured in any manner that could affect the reliability of its readings. The terrestrial radiation thermometer was unfortunately broken on the march to Camp Brown. The minimum-thermometer was also broken, but afterward observations were taken to get the minimum just before sunrise, which I think can safely be relied on. Observations for maximum are not so numerous as I wished to have them, because the column was generally on the march at that period of the day when it usually occurs. All altitudes are deduced from readings of the cistern barometer.

A careful comparison of the aneroids with a cistern, (1972,) in the office and on the march from Fort Bridger to Camp Brown, in all the circumstances of rapid and wide variations of temperature incident to hypsometrical observations, led me to look with suspicion upon their reliability. In bringing them down from great elevations, they require a long and erratic period of time for returning to their normal indications, while in going up they indicate the decrease of pressure too rapidly, thus leading to the excessive altitudes usually resulting from their use. It would seem as though the corrugated metallic box offers less resistance to expansion than compression, and that at high altitudes it is likely to take a set, thus preventing a complete return to the shape which it held at the lower level. Furthermore, where the diurnal variations of temperature are very wide, these aneroids, although compensated, were visibly affected by heat, and there is nothing to show to what extent. The result of office-comparisons is given below in Tables I, II, and III.

COMPARISON OF BAROMETERS.

TABLE I.

Omaha, Neb., altitude	1,000 feet.
Error of cistern-barometer No. 1972	+0.005
Error of cistern-barometer No. 1854	—0.042
Cupillarity	+0.004
Mean of 44 comparisons with 1972	—0.038
Fort Bridger, Wyo., altitude	6,639 feet.
Error of cistern-barometer, (1854.)	
Mean of 14 comparisons	—0.039
Probable constant error of No. 1854	—0.038

TABLE II.

*Aneroids.**

Omaha, Neb., elevation	1,000 feet.
Error of aneroid No. 1, (mean from 34 readings)	—0.118
Error of aneroid No. 2, (mean from 34 readings)	—0.043
Error of aneroid No. 3, (mean from 34 readings)	+0.034

TABLE III.

*Aneroids.**

Fort Bridger, Wyo., altitude		6,639 feet.
Mean from 23 comparisons	Error of aneroid No. 1	+0.524
	Error of aneroid No. 2	+0.667
	Error of aneroid No. 3	+0.646
Mean from 115 comparisons	Error of aneroid No. 1	+0.632
	Error of aneroid No. 2	+0.818
	Error of aneroid No. 3	+0.728

N. B.—These aneroids were compensated.

On the 16th of May I sent Mr. Putnam to Fort Bridger with all the barometers and other necessary instruments for making (before the expedition took the field) a thorough comparison of their readings. This he did very faithfully, and the result showed that my aneroids were not reliable, although I still hoped to use them for special trips, by comparing them immediately before leaving and at once after returning to camp. It soon appeared, however, that they were not fit even for this. The aneroid is a good weather-glass, but is hardly fit for hypsometrical work; this is a great pity, for there is great merit in its portability where mountains are to be climbed, and in its non-liability to breakage.

* Compared with No. 1972, (cistern,) at 32° Fahrenheit.

On the march from Fort Bridger the mercury in cistern-barometer 1854 leaked a little through the bag. The oxidation of this mercury between the threads of the elevating-screw soon clogged it, so that it could not be turned without great difficulty. Mr. C. T. Creary, who was carrying it, very ingeniously remedied the difficulty by making a wooden screw to work in its place. This answered the purpose admirably until we arrived at Camp Stambaugh, when he made a new screw of iron, that answered its purpose during the rest of the trip.

The leakage was caused by attempting to screw up the mercury until it filled the tube, in putting it up for transportation. This brings too much pressure on the bag of the cistern, and the mercury is crowded through it. It should only be screwed up until the cistern is full. The small motion in the mecurial column that is thus permitted does not endanger the instrument so much as the leakage when it is screwed up too tight. Works on meteorology do not call sufficient attention to this point, but rather convey the idea, if they do not positively direct, that the tube should be filled. The Smithsonian directions for meteorological observations, under the head of Barometer, say, page 17: "If circumstances compel this (moving) to be done, we should begin, before taking it from its place, by raising the mercury in the cistern by means of the screw so as to fill the cistern *and the* tube." Now, for transportation in the field, when at high altitudes, a comparatively large portion of the mercury gets into the cistern. This will not do at all, and, indeed, I should not think it advisable ever to screw up the mercury more than enough to fill the cistern.

In comparing these barometers, my attention has been particularly called to the unsatisfactory manner in which the attached thermometer registers the temperature of the mercury in the tube. Its bulb is placed in a small metallic case fastened to the outside of the brass frame of the barometer, which has a small hole sometimes cut in it opposite the bulb. It makes but little difference whether the hole is cut or not; the thermometer registers the temperature of a small inclosed space that receives the impress of increments or decrements of heat, somewhat less rapidly than the air outside, and the whole would make no sensible change in the readings. But the column of mercury is very slow to receive impressions of heat, and yet it is the temperature of this mercury that we *must* have in order to proceed with certainty to a common point of comparison for all observations. Here is undoubtedly the reason why no satisfactory results can be obtained in the comparison between two barometers. The true difference can only appear from the mean of a good many observations. In hypsometrical work this must be the cause of serious error, and when it is remedied the barometer will indeed be a remarkable leveling instrument.

Through the courtesy of the Chief Signal-Officer of the Army I have obtained the barometer-readings at Cheyenne, Corinne, and Fort Benton for the period covered by our trip. They have been plotted, and the results are shown in the accompanying chart. From these I was enabled to refer Camp Brown, our field-base, to Salt Lake City, at a time when the whole region was equally affected by barometric disturbance, thus insuring excellent altitude results, as an examination of the table of altitudes will show. To instance this I will call attention to the altitudes of Yellowstone Lake. We camped upon its shore five times, making almost the circuit around it. By leaving out one observation, that was not made at a proper time in the day for nice work, as the others were, it will be seen that the results compare quite closely. The mean of these gives 7,564 feet for the altitude of the lake, which, there is good reason for believing, is a fair approximation. I am somewhat specific on this point, because these figures differ so widely from those obtained by Professor Hayden, who, in 1871, finds this altitude to be 7,427 feet, and in 1872 finds it 7,788.

At Fort Bridger, Camp Brown, and the outlet of the Yellowstone Lake, I had hourly observations taken, for the purpose of getting an approximate horary curve for each. The results are given in the annexed chart, and will be of much interest.

The barometric readings at Corinne, Fort Benton, and Cheyenne, show that over the field embraced by the reconnaissance, the abnormal barometric oscillation was very nearly uniform. The computations for altitude were made by Lieut. S. E. Blunt, Thirteenth United States Infantry.

GREEN RIVER BASIN.

In the Green River Basin the diurnal temperature varies between pretty wide limits. This is largely owing to the extreme dryness of the atmosphere, which leaves almost nothing interposed to interfere with the radiation from the sun and earth. The relative humidity is very low, and dew and frost are quite rare. Rain seldom falls. The amount of solar radiation, as will be seen from the observations, is large, and the same causes that produce it will also probably produce a correspondingly large terrestrial radiation; all this indicates a severe climate.

The winds, with remarkable unanimity, are from the southwest and west, and the quantity of motion is great; a gale of wind can be confidently expected every day, commencing a little before noon. The natural tendency of the winds to come from the southwest over this region, is augmented by the local configuration of the ground. The west end of this basin is a *cul-de-sac*, with high mountains nearly surrounding it—the Uintahs on the south, the Wahsatch on the west, and the Wind River range on the north. The annexed sketch will illustrate it, (Fig. 8.)

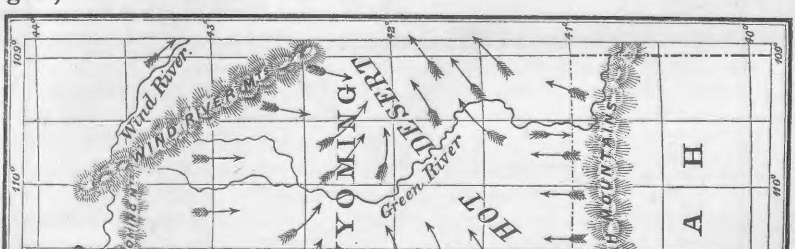


FIG. 8.—Explanation of winds in Green River Basin.

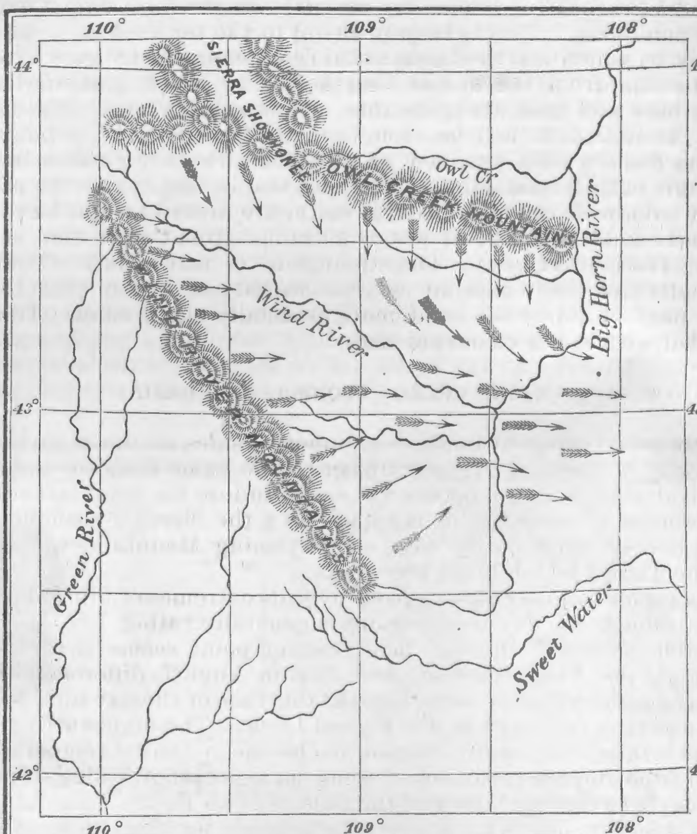
The air over the plateau becomes inordinately heated from radiation, while the cold air from the mountains rushes in to take its place, as it rises, and restore the equilibrium. The resultant motion thus produced is in a northwesterly direction, and as this is about the mean direction of the general currents of the air in this latitude, it will be seen that the different causes that tend to set the air in motion mutually re-enforce each other, producing the high winds that are such a well-known feature of the climate.

There are times when this local disturbance must be excessive, and perhaps we may look here for the origin, or at least a clew to it, of the storms that sweep across the continent to the eastward, and spend their fury on the Atlantic Ocean.

Local storms and squalls from the mountains sometimes descend a short distance into this basin, but generally clouds are rare, except the low fringe of cumuli on the horizon, that is so characteristic of fine weather.

WIND RIVER BASIN.

Fig. 9.



Explanation of winds in Wind River Basin.

The climate here is comparatively mild. The diurnal temperature has not such a great range as on the other side of the Wind River range, although in summer the air gets exceedingly warm about mid-day. The solar radiation is still very great, but terrestrial radiation is smaller, as the nights are warm. The relative humidity is also extremely low, causing a rarity of dew and frost. The mountains lying so close around, a slight rain-fall is caused by the summer showers from them, but the quantity of water that falls is very small. The general prevailing winds are entirely intercepted by the mountains, but the local disturbance caused by the air getting highly heated over the valley, and the rush of the cold air from the mountains to establish an equilibrium, is very great, causing daily currents of such strength and persistence as to give origin to the name of the river and mountains. This action is illustrated in the annexed sketch, (Fig. 9.)

THE BIG HORN BASIN.

The climate here is probably quite similar to that of the Wind River Valley; as far as our observations go such are the indications. There is the same and perhaps a somewhat greater cause for violent winds. The Indians repeatedly called my attention to the fact that it was very windy here, even more so than in the Wind River Valley. This is sufficiently accounted for by the fact that the mountains are very extensive, and the country at their feet and across to the Big Horn Range is mostly bare soil and rock, capable of becoming very strongly heated under the effects of the great solar radiation.

Away from the western face of the basin where the summer-squalls hang down from the edge of the mountains, the region is probably largely exempt from rain. This is further indicated by the fact that an extremely small quantity of water is drained from the western slopes of the Big Horn Mountains. The streams are of rare occurrence, and are frequently dry. On account of the scarcity of water, travel in the lower part of this basin, and more especially along its eastern face, is attended with much inconvenience.

UPPER YELLOWSTONE-TETON BASIN.

These two basins, although on opposite sides of the main divide of the Rocky Mountains, are yet subject to the same climatic influences; for this divide is so low between them as to lose its mountainous character almost entirely. This is supplied by the Sierra Shoshonee range which borders them on the east, the Wyoming Mountains to the south, and the Tetons which lie to the west.

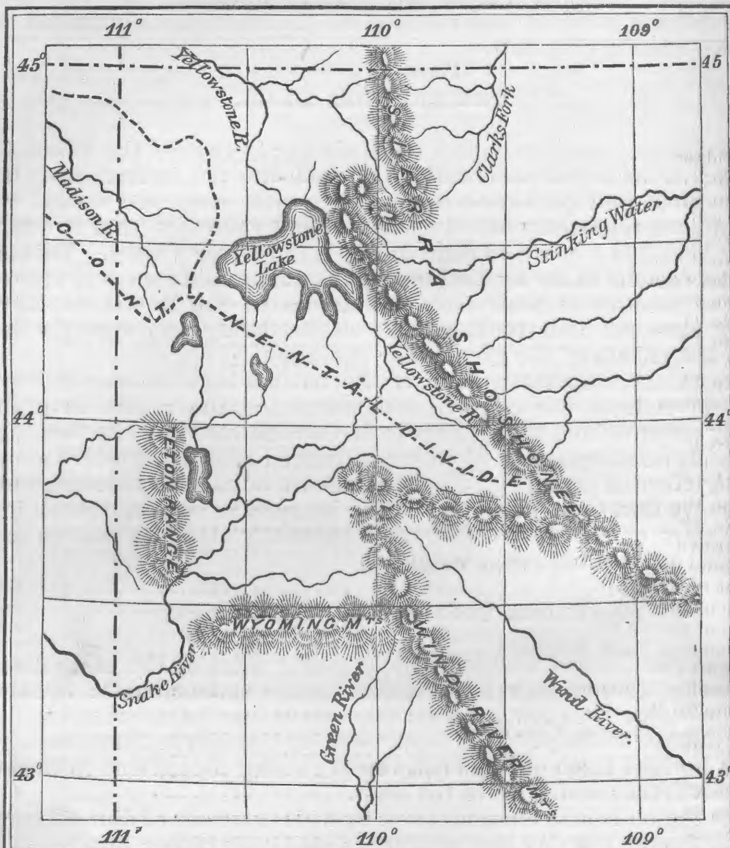
This region is also characterized by wide extremes of diurnal temperature, although the day temperature is generally rather low, making an agreeable summer climate. The freezing-point seems to obtain quite commonly just before sunrise; and late in August, different parties, in three consecutive years, have noted at this time of the day such very notable temperatures as 14° F., 13° F., and 12° F. The nights are extremely cold as a rule. An approximation to the mean annual temperature obtained from the temperatures of some springs east of Yellowstone Lake, and one between the lake and the falls, is 37°.5 F.

The relative humidity is remarkably high for the Rocky Mountain region, which is so generally characterized by the small proportion of aquous vapor in its atmosphere; as a natural attendant upon this exceptional feature, the whole region is densely timbered.

There is ample evidence of a moderately copious rain-fall in and around this basin, especially about the headwaters of Snake River, the vegetation is always fresh and tolerably luxuriant; the country is amply supplied with water in marsh, spring, stream, pond, and lake, and the meteorological records of parties who have visited it for three years in succession point clearly to it. We had several rainy days while traversing it, days in which the rain fell almost continuously during the night and day. This is a notable fact.

It is probably a region of severe storms; for an inspection of a general map, together with the annexed sketch, shows that the principal

Fig. 10.



Yellowstone—Teton Basin.

southwest air-current, moving over a low portion of the mountain mass of the Pacific coast, reaches the Teton's and Sierra Shoshonee range without being deprived of much of its vapor. It is not only checked in its course by this high, cool wall, but the tremendous acicular ridge of the Tetons stands in such a position as to produce a strong eddy about the headwaters of the Snake and over the lake basin.

The equable precipitation favors the growth of forest and rank vegetation, while the latter stores up the water, to be constantly vaporized and held ready for reprecipitation, the cause and effect each favorably acting upon the other. The indications are that this region along the western base of the Sierra Shoshone Mountains,* and lying between

*I use the word "mountains" in connection with *sierra* in deference to the custom of considering them words of different shades of meaning. To the majority of English-speaking people mountain is the only word that completely covers the idea involved.

the parallels of 43° 30′ and 45° 30′ north latitude, is one of equable precipitation. The severity of the summer frosts, however, will prevent any extensive tillage of the soil, which, by the way, is a rich black loam. The prevailing winds are westerly, and mild in their character.

Table of altitudes.

All observations with mercurial barometer.

Place.	Altitude.
	Feet.
Fort Bridger	6639.0
Camp No. 3	6308.3
Camp No. 5	6314.9
Camp No. 6	6210.2
Camp No. 8	6257.0
Camp No. 9	6569.2
Divide between Big Sandy and Little Sandy	6685.6
Camp No. 10	6657.6
Camp No. 11	6742.6
Camp No. 12	7134.0
Summit of South Pass	7480.0
Camp No. 13	7400.2
Camp Stambaugh	7767.1
Triangulation Station No 43	8267.1
Camp No. 15	6937.3
Bench at head of Red Cañon	6848.0
Camp No. 16	5407.1
Ranch on Big Popo Agie, (old Camp Brown)	5311.0
Camp No. 17	5447.3
Camp Brown	5498.4
From Camp Brown to Wind River Mountains:	
Foot of first hill	6600.0
Top of first hill	8034.0
Top of second hill	8857.0
Summit of Bald Mountain	9897.4
Timber-line	10760.0
Summit of Chimney Rock	11853.0
Camp No. 20	5792.7
Divide Sage Creek and Wind River	6096.5
Camp No. 21	5553.1
Camp No. 22, (across the river from Camp 21)	5556.5
Camp No. 23	6140.2
Camp No. 24	6320.0
Camp No. 25	6208.0
Pass over Owl Creek Mountains	7836.0
Summit east of pass	8233.0
Summit of Phlox Mountain	9136.0
Camp No. 26	6168.1
Camp on headwaters of Owl Creek	8610.0
Timber-line on the Washakee Needles	10683.0
Summit of the Washakee Needles	12253.0
Last divide before Camp No. 27	7074.7
Camp No. 27	6471.0
Hill south of Camp No. 27	6783.0
Camp No. 28	6120.8
Camp No. 29	5780.0
Camp No. 30	6166.4
Spur from the mountains	8607.1
Camp No. 31	7423.0
Camp No. 32	5273.2
Camp No. 33	5845.0
Camp No. 34	6041.6
Ridge S. S. W. from Camp 34, 1st point	7203.0
Ridge S. S. W. from Camp 34, 2d point	7284.0

Table of altitudes—Continued.

Place.	Altitude.
Ridge S. S. W. from Camp 34, 3d point	8062.0
Camp No. 35	6318.7
Camp No. 36	6683.0
Summit of Sailor Mountain	10046.0
Timber-line on Sailor Mountain	9746.0
Stinking-water Pass	9444.3
First triangulation-point north of pass	9938.1
Second triangulation-point north of pass	10027.9
Camp No. 37	8940.0
Yellowstone Lake, (at outlet)	7564.0
Camp No. 39	7491.8
Height of Upper Falls of the Yellowstone	150.2
Height of Great Falls of the Yellowstone	328.7
Camp No. 40	7908.0
Camp No. 41	5762.1
Jack Baronett's cabin	5741.5
Yellowstone River at bridge	5695.0
Camp No. 42	5813.7
Summit of Mount Washburne	10105.3
Camp No. 43	7724.0
Camp No. 44	8985.8
Camp No. 45	7132.4
Camp No. 46	7373.3
Camp No. 47	8301.7
Camp No. 48, (Yellowstone Lake)	7565.9
Camp No. 49, (Yellowstone Lake)	7564.0
Camp No. 50, (Yellowstone Lake)	7552.3
Camp No. 51, (Yellowstone Lake)	7563.1
Yellowstone Lake, (mean adopted)	7564.0
Summit of Mount Sheridan	10150.0
Camp No. 52	7787.7
Camp No. 53	7847.7
Camp No. 54	8080.9
Camp No. 55	7574.6
Camp No. 56	6892.4
Hill above Camp 56, (crossed by trail)	6892.4
Camp No. 57	8917.4
Togwotee Pass	9621.3
Mountain S. W. of pass	10625.4
Camp No. 58	7498.2
Camp No. 59	6942.0
Camp No. 60	6172.
Camp No. 61	5750.1
Camp No. 62, (Camp No. 20)	5799.6

TABLE I.—*Meteorological record of Northwest Wyoming Expedition from May* 19 *to September* 13, 1873.

Station.	Date.	Time.	Barometer.	Attached thermometer.	Detached thermometer.	Dry bulb.	Wet bulb.	CLOUDS. Kind.	CLOUDS. Amount.	WIND. Direction.	WIND. Force.	Remarks.
Fort Bridger, (elevation 6,639′)	May 19	9 0 a. m.	23. 400	43	......	44. 5	39. 5	......	...	......	...	Rain.
		10 0 a. m.	23. 400	44	......	44	39. 5	Cumulus	2	......	...	Rain.
		12 0 m ...	23. 390	45	......	45	39	Cumulus	5	......	...	
		1 0 p. m.	23. 390	48	......	47. 5	41	Cumulo-stratus	9	......	...	
		2 0 p. m.	23. 410	48	......	47	39	Cumulo-stratus	8	......	...	
		4 0 p. m.	23. 426	47	......	46	38	Stratus	6	......	...	
		6 0 p. m.	23. 460	44	......	46	37	Cumulus	1	......	...	
	May 20	8 0 a. m.	23. 480	40	......	41. 5	35. 5	Cumulus	1	......	...	
		9 0 a. m.	23. 476	44. 5	......	44	38	Cumulus	1	......	...	
		10 0 a. m.	23. 475	47	......	47	39	Cumulus	5	......	...	
		11 0 a. m.	23. 470	48	......	47	39	Cumulus	7	......	...	
		1 0 p. m.	23. 443	51	......	51	42	Cumulus	6	......	...	
		2 0 p. m.	23. 415	56	......	53	43	Cumulus	6	......	...	
		3 0 p. m.	23. 404	56	......	55	45	Cumulus	5	......	...	
		4 0 p. m.	23. 371	57	......	56	45	Cumulus	4	......	...	
		5 0 p. m.	23. 332	55	......	54	43	Nimbus	10	......	...	
		6 0 p. m.	23. 332	52	......	52	43. 5	Nimbus	10	......	...	Light rain.
	May 21	8 0 a. m.	23. 340	37	......	38. 5	34	Cumulus	2	......	...	Snow.
		9 0 a. m.	23. 320	38	......	38. 5	34	Cumulus	4	......	...	
		10 0 a. m.	23. 320	39	......	39	35	Cumulus	1	......	...	
		12 0 m ...	23. 313	40	......	40	35	Cumulus	1	......	...	
		2 0 p. m.	23. 356	45	......	43	36. 5	Cumulus	8	......	...	
		4 0 p. m.	23. 358	41	......	42	37	......	...	......	...	
	May 22	10 0 a. m.	23. 480	48	......	49. 5	43	Cumulus	1	......	...	
		11 0 a. m.	23. 472	47	......	49	43	Cumulus	1	......	...	
		12 0 m ...	23. 461	49	......	49	43	Cumulus	2	......	...	
		3 0 p. m.	23. 440	53. 5	......	54	47	Cumulo-stratus	6	North	2	
		4 0 p. m.	23. 438	53	......	54	46	Cumulus	9	......	...	
		5 0 p. m.	23. 423	53	......	53. 5	43. 5	Cumulus	9	......	...	
		6 0 p. m.	23. 426	51	......	52	44	Cumulus	9	......	...	
		7 0 p. m.	23. 432	50	......	52	45	Cumulus	9	......	...	
	May 23	6 0 a. m.	23. 397	44	......	46	40. 5	Stratus	8	East	2	
		7 0 a. m.	23. 386	45	......	47	42	Cumulus	6	East	2	
		8 0 a. m.	23. 372	46. 5	......	49	44	Cumulus	5	East	2	
		9 0 a. m.	23. 348	49	......	50	45	Cumulus	4	East	2	
		10 0 a. m.	23. 321	50	......	53	47	Cumulus	3	East	2	
		11 0 a. m.	23. 387	51	......	52. 5	46. 5	Cirro-cumulus	5	East	2	Storm to west.
		12 0 m ...	23. 254	52	......	55	48	Cumulus	8	East	1	Storm to west.

TABLE I.—*Meteorological record of Northwest Wyoming Expedition from May 19 to September 13, 1873*—Continued.

Station.	Date.	Time.	Barometer.	Attached thermometer.	Detached thermometer.	Dry bulb.	Wet bulb.	CLOUDS.		WIND.		Remarks.
								Kind.	Amount.	Direction.	Force.	
Fort Bridger	May 23	2 0 p. m.	23. 282	52	......	51	46	Cumulo-nimbus	9	Southwest	3	Storm to southwest.
		3 0 p. m.	23. 302	50	......	50	45	Cumulo-stratus	10	West	3	
		4 0 p. m.	23. 335	48	......	49	44	Nimbus	10	....	...	Rain.
		6 0 p. m.	23. 352	48	......	50	44	Nimbus	10	....	...	Rain.
		7 0 p. m.	23. 364	48	......	50. 5	44. 5	Nimbus	9	West	2	Clearing.
	May 24	6 0 a. m.	23. 380	42	......	44	40	Nimbus	9	South	0	
		7 0 a. m.	23. 386	43	......	45	40	Nimbus	9	South	0	Snow.
		8 0 a. m.	23. 397	44	......	46	41	Nimbus	10	....	0	Snow.
		9 0 a. m.	23. 401	46. 5	......	47	42	Nimbus	9	West	1	
		10 0 a. m.	23. 413	47	......	47	42	Nimbus	10	West	1	Snow.
		11 0 a. m.	23. 416	45. 5	......	47	42	Nimbus	10	West	2	Snow and rain.
		12 0 m	23. 408	45. 5	......	45	42	Cumulus	6	West	2	Sleet.
		1 0 p. m.	23. 415	46	......	46	42	Nimbus	10	West	3	Rain.
		2 0 p. m.	23. 418	45. 5	......	46. 5	42. 5	Cumulus	5	West	3	
		3 0 p. m.	23. 418	47	......	47	43	Cumulus	4	West	3	
		4 0 p. m.	23. 437	48	......	46. 5	44	Cumulus	7	West	3	
		5 0 p. m.	23. 448	48	......	50	45	Cumulus	8	West	3	Light rain.
		6 0 p. m.	23. 452	47. 5	......	48	44	Cumulo-stratus, nimbo-cirrus	4	West	2	Light rain.
		7 0 p. m.	23. 464	47. 5	......	48	43. 5	Cumulo-stratus, nimbus	6	West	1	
	May 25	6 0 a. m.	23. 504	42	......	45. 5	41	Cumulo-stratus	6	West	1	
		7 0 a. m.	23. 509	44	......	45	40. 5	Cumulus	4	West	2	
		8 0 a. m.	23. 523	44	......	45. 5	41	Cumulus	9	West	2	
		9 0 a. m.	23. 523	45	......	45. 5	41. 5	Cumulus	8	West	2	
		10 0 a. m.	23. 521	47	......	48. 5	43. 5	Cumulus	3	West	1	
		11 0 a. m.	23. 523	50. 5	......	51	45. 5	Cumulus	6	West	1	
		12 0 m	23. 520	50	......	50	44. 5	Cumulus	8	West	1	
		1 0 p. m.	23. 520	51	......	50	45	Cumulus	8	West	1	
		3 0 p. m.	23. 508	50	......	51	45	Cumulus	3	North	2	
		4 0 p. m.	23. 504	50	......	50. 5	44	Cumulus	3	North	2	
		7 0 p. m.	23. 520	53	......	53	46	Cumulo-stratus	3	West	1	
	May 26	7 0 a. m.	23. 492	44	......	45. 5	40	....	0	North	1	
		8 0 a. m.	23. 491	46	......	46. 5	41	....	0	North	1	
		9 0 a. m.	23. 476	48	......	48	43	Cumulus	1	West	0	
		10 0 a. m.	23. 472	49	......	48	43	Cirrus	2	West	2	
		11 0 a. m.	23. 447	52	......	52	45	Cirro-stratus	5	West	2	
		12 0 m	23. 440	53	......	52	45	Cumulus, cirro-stratus	5	West	2	
		1 0 p. m.	23. 440	55	......	54. 5	45	Cirro-cumulus	7	West	2	
		6 0 p. m.	23. 418	52	......	55	48	Cumulo-stratus	8	West	2	
	May 27	6 0 a. m.	23. 436	48	......	47	42	....	0	....	0	

		7	0 a. m.	23.444	48.5	......	50	44.5	....	0	....		
		11	0 a. m.	23.418	51	......	53	46.5	Cumulus........................	1	Northwest....	1	
		1	0 p. m.	23.392	54	......	56.5	49	Cumulus........................	6	West	2	Light rain.
		6	0 p. m.	23.323	50	......	51	46.5	....	...	....	...	
	May 28	6	0 a. m.	23.176	39	......	46	44.5	Fog........................		Southeast.....	1	Heavy dew.
		8	0 a. m.	23.137	51	......	56	51	Cumulus........................	2	Southeast....	1	
		10	0 a. m.	23.158	67	......	70	54	Cumulus........................	2	West	2	
		12	0 m....	23.140	58	......	65	50.5	Cumulo-nimbus.............	9	South..........	3	Storm to south.
		1	0 p. m.	23.124	62.5	......	62.5	50	Cumulus.....................	9	West	3	Light rain.
Fort Bridger....................	May 28	2	0 p. m.	23.120	68	......	70	52.5	Cumulus........................	5	West	3	
		3	0 p. m.	23.187	49	......	51	43	Cirro-cumulus, cirro-stratus.	3	Northwest....	3	
		6	0 p. m.	23.198	45	......	48	41	Cumulo-stratus	9	Northwest....	2	
	May 29	6	0 a. m.	23.337	36	......	39	37	Cirro-cumulus, cumulo-strat.	8	West	3	Ice one-eighth inch.
		7	0 a. m.	23.369	44.5	......	46	41.5	Cirro-cumulus	7	West	1	
		11	0 a. m.	23.377	52	......	53	44	Cirro-cumulus	3	East	2	
		12	0 m.	23.361	55	......	56	45	....	...	....	...	
		2	0 p. m.	23.326	55	......	69	55	Cirro-cumulus, cumulo-strat.	8	North	1	
		4	0 p. m.	23.267	63	......	63	49	Cumulus........................	8	South..........	1	
		6	0 p. m.	23.244	56	......	......	......	Nimbus........................	9	West	2	
		8	0 p. m.	23.248	45.5	......	47	42	Nimbus........................	9	West	2	
	May 30	5	0 a. m.	23.347	32.5	......	34	32.5	Cumulo-stratus	6	Southwest....	1	Ice one-eighth inch.
		6	0 a. m.	23.349	33.5	......	35	33	Cumulo-stratus	6	Southwest....	1	
		7	0 a. m.	23.363	36	......	37	35	Cirro-stratus.................	4	North	1	
		10	0 a. m.	23.434	50.5	......	52	45	Cumulus........................	8	West	3	
		1	0 p. m.	23.488	54	......	54	46	Cumulus, nimbus	9	West	4	
		2	0 p. m.	23.540	59	......	63.5	51.5	Cumulus........................	7	West	3	
		6	0 p. m.	23.583	47.5	......	45	38	Cirro-cumulus	2	West	2	
		7	0 p. m.	23.597	50	......	50.5	44	Cirro-stratus.................	1	West	2	
		8	0 p. m.	23.597	39	......	38	35.5	Stratus	1	West	2	
	May 31	7	0 a. m.	23.664	41	......	46	37	....	0	North	1	
		8	0 a. m.	23.670	44	......	44.5	35	....	0	East	1	
		11	0 a. m.	23.676	62	......	67	......	....	0	East	1	
		12	0 m.	23.669	62	......	74	55	Cirrus	1	....	...	
		2	0 p. m.	23.665	79	......	82	61	Cirrus	3	Northwest....	1	
		5	0 p. m.	23.600	60	......	60	48	....	...	....	...	
		6	0 p. m.	23.606	61	......	63	51	Cumulo-stratus	6	West	2	
		7	0 p. m.	23.602	50	......	50	44	Stratus	9	West	3	
		8	0 p. m.	23.608	48	......	49	......	Cumulo-stratus	9	West	3	
	June 1	7	0 a. m.	23.670	48	......	53	46	....	0	West	1	
		8	0 a. m.	23.682	58.5	1	64	......	....	0	West	1	
		1	0 p. m.	23.684	71.5	......	75.5	57	....	0	West	2	
		4	0 p. m.	23.656	72.5	......	72.5	......	Cirrus	1	West	2	
		6	0 p. m.	23.649	70	......	69	......	....	0	West	2	
		9	0 p. m.	23.622	37	......	37	......	....	0	West	1	
	June 2	6	0 a. m.	23.660	48.5	......	52.5	46.5	....	0	Northwest....	1	
		7	0 a. m.	23.678	57	......	59	48.5	....	0	Northwest....	1	
		8	0 a. m.	23.683	69	......	61	49	....	0	East	1	
		9	0 a. m.	23.683	64	......	67	52	....	0	East	2	
		2	0 p. m.	23.665	75	......	75	56	Cumulus........................	1	West	2	
		7	0 p. m.	23.622	62.5	......	60.5	47	Cirro-stratus	1	Northwest....	2	
		8	0 p. m.	23.614	51.5	......	50	41	....	0	West	1	
		9	0 p. m.	23.604	40	......	40	35	....	0	West	0	Slight aurora.

TABLE I.—*Meteorological record of Northwest Wyoming Expedition from May 19 to September 13, 1873*—Continued.

Station.	Date.	Time.	Barometer.	Attached thermometer.	Detached thermometer.	Dry bulb.	Wet bulb.	CLOUDS. Kind.	CLOUDS. Amount.	WIND. Direction.	WIND. Force.	Remarks.
Fort Bridger	June 3	7 0 a.m.	23.689	58	......	62	51	Cirrus	1	West	0	
		8 0 a.m.	23 689	58	......	59	47	Cirrus	1	Northeast	1	
		9 0 a.m.	23.689	61.5	......	62.5	47	......	0	Northeast	1	
		10 0 a.m.	23.689	64.5	......	65.5	50	Cumulus	1	Northeast	1	
		11 0 a.m.	23.683	69	......	73	55	Cumulus	1	North	1	
		1 0 p.m.	23.683	80	......	87.5	63	Cumulus	1	North	1	Showers in mountains.
		2 0 p.m.	23.664	79.5	......	82.5	61	Cumulus	1	West	1	Do.
		4 0 p.m.	23.635	79	......	76	53	Cumulus	2	West	1	
		7 0 p.m.	23.603	65	......	63	52	Cirro-cumulus	1	Northwest	1	
		8 0 p.m.	23.584	52	......	50	44	Cirrus	5	North	1	
	June 4	6 0 a.m.	23.681	50.5	......	52.5	46.5	......	0	West	1	
		7 0 a.m.	23.691	58	......	59.5	51	......	0	West	1	
		2 0 p.m.	23.532	76.5	......	......	......	Cumulo-stratus	2	West	1	
		7 0 p.m.	23.509	61.5	......	......	......	Nimbus	1	Northwest	1	Showery to east.
		9 0 p.m.	23.505	44	......	......	......	......	0	South	1	
	June 5	7 0 a.m.	23.574	63	......	......	......	Cirrus	1	North	1	
		10 0 a.m.	23.594	78	......	......	......	Cirro-cumulus	1	Southwest	1	
		12 0 m.	23.588	78	......	......	......	Cumulus	2	West	2	
		3 0 p.m.	23.567	79	......	......	......	Cumulus	1	West	1	
		6 0 p.m.	23.538	72.5	......	......	......	......	......	West	2	
		9 0 p.m.	23.539	47	......	47	42	......	0	South	1	
	June 6	5 0 a.m.	23.532	47.5	......	50	......	......	0	West	1	
	June 7	12 0 m.	23.564	74	74	......	......	Cumulus	3	......	0	
		6 0 p.m.	23.574	69	65	......	......	Nimbus	3	West	0	
	June 8	7 0 a.m.	23.652	49	50	......	......	......	......	......	......	
		9 0 a.m.	23.664	61.5	69	......	......	......	......	......	......	
		11 0 a.m.	23.686	71	70	......	......	......	......	......	......	
		12 30 p.m.	23.674	73	70	......	......	......	......	......	......	
		3 30 p.m.	23.634	64	62	......	......	......	......	......	......	
		6 0 p.m.	23.610	54	57	......	......	......	......	......	......	
		9 0 p.m.	23.634	48.5	48	......	......	......	......	......	......	
	June 9	7 0 a.m.	23.668	47.5	47	......	......	......	0	......	0	
		2 0 p.m.	23.666	76	72	......	......	Cumulus	1	West	1	Instrum'ts exposed to sun.
		6 0 p.m.	23.629	65.5	63.5	......	......	Cumulus	1	Southwest	1	Do.
		9 0 p.m.	23.614	44	45	......	......	......	0	......	0	
	June 10	6 0 a.m.	23.624	46.2	50	......	......	......	......	......	......	
		7 0 a.m.	23.668	63.5	56	......	......	......	0	West	1	Do.
		12 30 p.m.	23.653	78.5	78.5	......	......	......	0	West	1	Do.
		2 0 p.m.	23.644	86	86.5	......	......	Cumulus	1	West	2	Do.

		9 0 p. m.	23. 596	51. 5	54	......	......	....	0	West	1	
	June 11	6 0 a. m.	23. 592	53	54	......	......	Cirro-cumulus	2	South.........	1	
		12 15 p. m.	23. 644	79	74	......	......	Cumulus.....................	4	West	2	Do.
		2 0 p. m.	23. 632	73	71. 5	......	......	Cumulus.....................	8	Southwest ...	2	Instrum'ts exposed to sun; a few drops of rain.
		9 0 p. m.	23. 634	50	45	......	......	Stratus	1	South	1	
	June 12	7 0 a. m.	23. 728	71. 5	65. 5	......	......	Cirrus	2	West	1	
Camp 3, (6,308′)	June 12	7 30 p. m.	24. 004	63	62. 7	......	......	Cirro-stratus	1	West	1	
	June 13	8 15 a. m.	24. 013	72	67	......	......	....	0	West	1	
Camp 5, (6,315′)	June 14	9 0 a. m.	24. 016	78	......	68	57	Cumulus.....................	1	....	0	
		12 m	23. 982	80. 5	......	80. 5	59. 5	Cumulus.....................	6	South.........	1	
		3 0 p. m.	23. 948	85. 5	......	78	......	Cirrus	2	West	2	
		7 0 p. m.	23. 922	65	......	64	53. 5	Cirrus, cumulo-stratus	7	West	1	
Camp 6, (6,210′)	June 15	4 30 p. m.	24. 038	77	73	......	......	Cumulus, cirrus, nimbus	8	East	2	
		6 0 p. m.	24. 036	71	70. 5	......	......	Nimbus, cumulus, cirrus	8	Southeast.....	2	Thundering.
	June 16	7 0 a. m.	24. 049	57	55. 5	......	......	Cumulus, nimbus............	6	East	1	Instrum'ts exposed to sun
Camp 7	June 16	11 0 a. m.	24. 057	85	78	93	70	Cumulus, cirrus............	2	South.........	2	Do.
		12 m	24. 046	86	83	96. 5	......	Cumulus, nimbus	7	Southeast.....	3	Do.
		2 0 p. m.	24. 032	86. 5	82	93	68	Cumulus, nimbus	6	West	3	Do.
		6 0 p. m.	23. 995	71	67	65	55	Cumulo-stratus	8	West	1	Do.
Station-house south side of Big Sandy	June 17	12 m	23. 962	80. 5	81. 5	......	......	Cirro-stratus..............	7	West	2	
		1 0 p. m.	23. 949	77	78	......	......	Cirro-stratus..............	7	West	2	
Camp 8, (6,257′)..................	June 17	8 0 p. m.	23. 898	57	55	......	......	Cirro-stratus..............	1	West	0	
	June 18	4 30 a. m.	23. 810	41	41	......	......	Cirrus	1	East	0	
Station-house crossing of Big Sandy	June 18	2 30 p. m.	23. 642	77. 8	78. 2	......	......	Cirrus	4	West	2	
		4 30 p. m.	23. 640	77	76. 5	......	......	Cirro-cumulus	4	West	2	
Camp 9, (6,569′)	June 19	5 30 a. m.	23. 705	57	48	......	......	Cirrus	1	Southeast.....	0	
Camp 10, (6,658′)..................	....	2 0 p. m.	23. 634	88	88	68	60	Cumulus.....................	1	East	2	Do.
		6 0 p. m.	23. 573	84. 8	82. 6	82	56. 7	Cumulus.....................	1	Southwest ...	2	
		9 0 p. m.	23. 534	57. 5	52. 5	54	47	Stratus	1	....	0	
	June 20	6 0 a. m.	23. 558	59. 3	55	59	49. 5	Cirro-stratus..............	1	North.........	0	
		12 m	23. 570	85	......	90	60. 5	Cumulus.....................	1	South.........	3	
		2 0 p. m.	23. 510	88	92	89	59. 5	....	0	South.........	4	
		8 0 p. m.	23. 472	68	66	67	48	Cumulo-stratus	1	West	2	
	June 21	12 m	23. 442	81. 5	83	79. 5	55	Cumulus.....................	4	South.........	4	
Camp 11, (6,743′)..................	June 21	7 30 p. m.	23. 102	61. 2	58. 5	......	......	Stratus	3	....	0	
	June 22	5 0 a. m.	23. 110	48	45. 5	......	......	Nimbus, cumulo-stratus	8	West	2	A few drops of rain.
Dry Sandy station-house..........	June 22	7 0 a. m.	23. 138	40	41	......	......	Nimbus.....................	10	Southwest	3	Hard rain and snow.
Camp 12, (7,134′)	June 22	4 0 p. m.	22. 986	52	50. 5	......	......	Cumulus.....................	7	West	4	
		5 0 p. m.	22. 992	49	48	......	......	Cumulus.....................	6	West	3	
	June 23	6 0 a. m.	23. 126	52	55	49	41	....	0	West	2	
		12 m......	23. 148	56	57	57	......	Cumulus.....................	1	South.........	2	
Summit of South Pass, (7,480′).....	June 23	3 30 p. m.	22. 788	59	52	......	......	....	0	West	2	
Camp 13, (7,400′)	June 23	6 30 p. m.	22. 858	55	51	......	......	....	0	West	1	
	June 24	5 0 a. m.	22. 830	36	29	......	......	Stratus	1	East	2	
Camp Stambaugh, (7,767′)	June 24	7 20 p. m.	22. 516	65. 5	60. 5	......	......	Cumulo-stratus	1	West	1	
	June 25	7 0 a. m.	22. 567	62	62	......	......	....	0	West	2	
		9 0 a. m.	22. 568	77. 5	78	......	......	....	0	Southwest	2	
		10 0 a. m.	22. 575	70	69. 5	......	......	....	0	Southwest	2	
		11 0 a. m.	22. 572	70	71	......	......	....	0	Southwest	3	

TABLE I.—*Meteorological record of Northwest Wyoming Expedition from May* 19 *to September* 13, 1873—Continued.

Station.	Date.	Time.	Barometer.	Attached thermometer.	Detached thermometer.	Dry bulb.	Wet bulb.	CLOUDS.		WIND.		Remarks.
								Kind.	Amount.	Direction.	Force.	
Camp Stambaugh, (7,767′)	June 25	12 m	22.576	73.8	76.5				0	South	3	
		1 0 p. m.	22.568	74	79				0	South	3	
		2 0 p. m.	22.576	73	74.5	75	46		0	Southwest	4	
		3 0 p. m.	22.562	75					0	Southwest	4	
		4 0 p. m.	22.594	74.5	74				0	Southwest	4	
		6 0 p. m.	22.598	73	70	70.5	44.5		0	Southwest	3	
		8 0 p. m.	22.640	68	60			Cumulo-stratus	1	Southwest	2	
		9 0 p. m.	22.610	69	57.5				0	Southwest	2	
		10 0 p. m.	22.690	68	63				0	Southwest	1	
		11 0 p. m.	22.676	68.5	54							
		12 m	22.680	67.5	51.5							
	June 26	1 0 a. m.	22.708	67.5	46.5							
		2 0 a. m.	22.710	66.5	44.5							
		3 0 a. m.	22.735	65.5	42.5							
		4 0 a. m.	22.740	65	41.5							
		5 0 a. m.	22.764	62	42.5							
		6 0 a. m.	22.758	61	51	64.8	45.5		0	West	1	
		7 0 a. m.	22.774	64	61				0	Southwest	2	
		8 0 a. m.	22.790	68	65.5				0	Southwest	2	
		9 0 a. m.	22.806	69.5	68				0	Southwest	2	
		10 0 a. m.	22.808	72.5	71				0	Southwest	2	
		11 0 a. m.	22.815	74	70.5				0	Southwest	2	
		12 m	22.810	75	77.5	75	47.5		0	Southwest	2	
		1 0 p. m.	22.811	75.5	81.5				0	Southwest	3	
		2 0 p. m.	22.811	74	75	76.5	47.5		0	Southwest	3	
		3 0 p. m.	22.813	75	74.5				0	Southwest	2	
		4 0 p. m.	22.808	76	76				0	Southwest	1	
		5 0 p. m.	22.816	73.5	73.5				0	Southwest	1	
		6 0 p. m.	22.820	71.5	70	71	45.5		0	West	1	
		8 0 p. m.	22.838	69	57				0	Southwest	0	
		9 0 p. m.	22.848	67	54				0	West	0	
	June 27	7 0 a. m.	22.875	65	64.5				0	Southwest	1	
		8 0 a. m.	22.884	69	68.5				0	Southwest	1	
		9 0 a. m.	22.880	72	72				0	West	1	
		12 m	22.882	75	80	76.5	48		0	Southwest	2	
		2 0 p. m.	22.873	74.5	74	75	46		0	West	3	
		6 0 p. m.	22.850	74	69	69.5	43.5		0	West	2	
		8 0 p. m.	22.848	70	57				0	West	2	
		9 0 p. m.	22.851	68	56			Stratus	1	West	2	

	June 28	6 0 a. m.	22. 838	61. 2	58			Cirro-cumulus	1	Southwest		
Camp 15, (6,937')	June 28	7 15 p. m.	23. 332	53	44			Cirrus	1	Southwest		
Camp 16, (5,407')	June 29	12 m	24. 713	88	76			Cumulus	1	Southeast		
		2 0 p. m.	24. 663	87	76			Cumulus	1	North	1	
		6 0 p. m.	24. 573	75	74	74	57	Cumulus	1		0	
	June 30	4 15 a. m.	24. 533	46	45			Cumulo-stratus	3		0	
Ranch on Baldwin Creek, (5,311')	June 30	12 30 p. m.	24. 620	67. 5	66			Cumulus	8	South	1	
		1 15 p. m.	24. 630	71. 5	70. 5			Cumulo-stratus	7	South	1	Light rain.
Camp 17, (5,447')	June 30	3 45 p. m.	24. 551	66	64			Cumulus	3	West	1	Rain.
		8 0 p. m.	24. 531	51	51			Cumulo-stratus	6	South	1	
	July	5 0 a. m.	24. 468	41. 5	42							
		6 0 a. m.	24. 472	48. 2	54			Cirro-cumulus, cirro-stratus	1		0	
Camp Brown, (5,498')	July 2	12 m	24. 420	76. 5	79	78. 8	56	Cumulus	8	West	2	
		2 0 p. m.	24. 406	78. 5	80	80. 5	54. 5	Cumulus	3	West	2	
		8 15 p. m.	24. 440	73	66			Cirrus, cumulo-stratus	2	West	1	
	July 3	7 0 a. m.	24. 472	63	58	67	52. 5		0		0	
		8 0 a. m.	24. 507	68	64				0	East	1	
		9 0 a. m.	24. 510	72	68				0	East	1	
		10 0 a. m.	24. 509	73	71			Cirro-stratus	1	East	1	
		11 0 a. m.	24. 508	75. 5	74			Cirro-stratus	1		0	
		12 m	24. 510	77	78	78. 9	51	Cirrus	1	West	2	
		1 0 p. m.	24. 508	77. 8	80			Cirrus	1	West	2	
		2 0 p. m.	24. 510	79. 5	81	82	52. 5	Cirrus	1	West	2	
		3 0 p. m.	24. 512	81	83			Cirrus	1	West	2	
		4 0 p. m.	24. 512	83. 5	84			Cirrus	1	West	2	
		5 0 p. m.	24. 532	81. 5	82			Cirrus	1	West	2	
		6 0 p. m.	24. 544	82	79			Cirrus	1	West	1	
		7 0 p. m.	24. 557	78. 3	74	72	51	Cirrus	3	West	1	
		8 0 p. m.	24. 586	75	67			Cirro-stratus	2	West	1	
		9 0 p. m.	24. 592	72. 5	64							
		10 0 p. m.	24. 600	70. 5	62							
		11 0 p. m.	24. 608	72	62							
		12 m	24. 610	70	60							
	July 4	1 0 a. m.	24. 616	69. 5	59							
		2 0 a. m.	24. 620	68. 5	62							
		3 0 a. m.	24. 626	67. 6	59							
		4 0 a. m.	24. 622	66. 7	52. 4							
		5 0 a. m.	24. 664	66	52				0		0	
		6 0 a. m.	24. 673	64. 5	56				0	West	1	
		7 0 a. m.	24. 672	66	61	69. 5	52. 5		0	West	0	
		8 0 a. m.	24. 676	69. 5	66				0	East	1	
		10 0 a. m.	24. 670	75. 5	72							
		11 0 a. m.	24. 664	78. 5	76							
		12 m	24. 652	81	79							
		2 0 p. m.	24. 640	83	84	86	55. 2		0	West	2	
		7 0 p. m.	24. 628	83. 5	77	73	55		0	West	2	
	July 5	9 20 a. m.	24. 680	78	75							
		12 m	24. 652	84. 5	87	86	60. 5					
		2 0 p. m.	24. 646	86. 5	89	87. 5	59. 5					
		4 0 p. m.	24. 628	86	87	87. 5	61					
		6 0 p. m.	24. 634	86	85	85. 5	60. 5					
		9 0 p. m.	24. 612	72. 5	66	63	53					

TABLE I.—*Meteorological record of Northwest Wyoming Expedition from May 19 to September 13, 1873*—Continued.

Station.	Date.	Time.	Barometer.	Attached thermometer.	Detached thermometer.	Dry bulb.	Wet bulb.	CLOUDS. Kind.	CLOUDS. Amount.	WIND. Direction.	WIND. Force.	Remarks.
Camp Brown, (5,498′)	July 6	7 0 a. m.	24.682	71.5	68	71.5	58					
		9 0 a. m.	24.680	76.5	75.5	76.5	58	Cumulus	6			
		12 m	24.666	86.5	87	88.5	62	Cumulo-stratus	8			Few drops of rain.
		2 0 p. m.	24.688	80.5	78	78	56.5	Cumulo-stratus	9			Light rain.
		7 0 p. m.	24.678	76	77.5	76.5	57.5	Stratus, nimbus	2			
		10 0 p. m.	24.670	70.5								
	July 7	7 0 a. m.	24.698	66.5	54	54.5	33					
		8 0 a. m.	24.696	70	73	73	56					
		9 0 a. m.	24.708	75.5	74							
		10 0 a. m.	24.710	77	76							
		11 0 a. m.	24.710	80	78.5							
		12 m	24.692	82	80.5	81.5	60					
		1 0 p. m.	24.674	84.5	83	84.5	61					
		2 0 p. m.	24.658	88	87.5							
		3 0 p. m.	24.652	87	82			Nimbus, cumulo-stratus	9	Southwest	0	Showering.
		4 0 p. m.	24.636	85	81	81	61.5	Nimbus, cumulo-stratus	9			
		5 0 p. m.	24.620	82	79	89.5	59	Nimbus, cumulo-stratus	9			
		6 0 p. m.	24.634	81.5	77.5	77.5	57.5	Nimbus, cumulo-stratus	7	East	1	
Camp Brown, (5,498′)	July 8	7 0 a. m.	24.674	68.5	67	67.5	57.5					
		9 0 a. m.	24.676	75.5	76							
		12 m.	24.674	85.5	82.5	83.5	60					
		2 0 p. m.	24.654	85.5	82							
		5 0 p. m.	24.622	90.7	84.3			Cumulus	2	West	2	Wind-storm between 3 and 4 p. m.
		6 0 p. m.	24.636	80.5	77	77.5	58	Cumulus, nimbus	2	Northwest	2	
		9 30 p. m.	24.723	73	68			Cumulus, nimbus	9	North	3	
	July 9	7 0 a. m.	24.749	67.	66	66.5	56		0	North	0	
		12 m.	24.766	80.5	77.5			Cumulus	1		0	
		6 0 p. m.	24.730	89.9	81.5	83	61	Cirro-cumulus	1	North	1	
	July 10	7 0 a. m.	24.700	69.5	67	68	58.5	Cirro-cumulus	5	North	1	
Camp 19	July 11	7 0 a. m.	24.640	66.5	69			Cumulo-stratus	8		0	
		12 15 p. m.	24.603	87	90			Nimbus, cumulus	4	Southeast	1	
Camp 20, (5,793′)	July 12	7 0 a. m.	24.348	63	62			Cumulus	1	West	1	
Camp 21, (5,553′)	July 12	8 0 p. m.	24.412	67.5	68			Stratus	4	South	1	
	July 13	6 0 a. m.	24.515	53	56			Cirro-cumulus, cumulo-strat.	8	South	0	
		7 0 a. m.	24.532	66.5	61.5	59.5	50.5	Cirro-cumulus, stratus	3	East	1	
		12 15 p. m.	24.515	72	72	71.5	51.5	Cumulus, cumulo-stratus	6	West	3	Shower in Wind River Mountains.
		3 0 p. m.	24.546	74.6	75			Cumulus	2	West	1-3	Wind westerly.

Camp 22, (5,556′)	July 13	8 0 p. m.	24. 563	62	56			Cumulus	1	South	1	
	July 14	6 0 a. m.	24. 605	59	53				0	Southwest	1	
		7 0 a. m.	24. 610	63. 6	61				0	South	0	
Camp 23, (6,140′)	July 14	7 0 p. m.	24. 007	73. 7	72. 5				0	West	2	
		8 0 p. m.	23. 996	65. 5	65				0	West	1	Brilliant meteor at 8.35 p.m.
	July 15	7 0 a. m.	24. 030	66. 3	65. 5			Cumulus	1	West	0	
		12 m.	24. 030	86	84			Cirro-stratus	5	West	1	
Camp 24, (6,320′)	July 15	7 0 p. m.	23. 511	74	72			Cumulo-stratus	7	South	2	
	July 16	7 0 a. m.	23. 590	69	76. 5				0	West	2-4	
Camp 25, (6,208′)	July 16	8 0 p. m.	23. 798	62	61				0	Northwest	2-3	
	July 17	7 0 a. m.	23. 949	62. 5	57				0	Southwest	1	
Highest point on trail over Owl Creek Mountains, (7,836′)	July 17	10 0 a. m.	22. 636	67	60			Hazy		North	2	
Summit, east of pass, (8,233′)	July 17	11 15 a. m.	22. 303	60. 1	58			Hazy		North	2	
Camp 26, (6,168)	July 17	6 0 p. m.	24. 080	71	68				0	East	1	
	July 18	4 30 a. m.	24. 084	46	47				0	Southeast	1	
Camp on Dry Creek	July 18	2 0 p. m.	22. 859	69. 8	69. 5				0	Southwest	1	
Headwaters of Owl Creek, (8,610′)	July 18	8 0 p. m.	22. 142	43. 5	44				0	West	1	
	July 19	4 30 a. m.	22. 092	36	34				0	West	1	
		6 0 a. m.	22. 108	51. 5	51. 5				0	West	1	
Highest point reached on Washakie Needles, (12,053′)	July 19	2 0 p. m.	19. 406	57. 5								
Timber-line on Washakie Needles, (10,683′)	July 19	3 0 p. m.	20. 608	62								Light rain.
Camp 26, (6,168′)	July 20	2 0 p. m.	23. 864	89	91			Cumulus, stratus	8	West	2	
		7 30 p. m.	23. 802	77. 5	77				4	West		
	July 21	6 45 a. m.	23. 730	72	71			Cirro-cumulus, cumulo-strat.	8	West	2	
Last divide before reaching Camp 27, (7,075′)	July 21	3 0 p. m.	23. 196	84	77. 5			Cirrus, cumulo-stratus	8	West	2	
Camp 27, (6,471′)	July 21	6 30 p. m.	23. 884	69. 5	68			Nimbus	9	North	1	
		8 0 p. m.	23. 886	62. 5	65			Cumulo-stratus	7		0	
	July 22	4 45 a. m.	23. 968	47. 5	45. 5			Cirro	½	Northwest	0	
		6 0 a. m.	23. 991	65	65			Cirro	½	Northwest	0	
Camp 28, (6,121′)	July 22	2 0 p. m.	24. 232	82. 3	81			Cirro	4	West	1	
		8 0 p. m.	24. 245	59	58			Cumulo-stratus	8	West	1	
	July 23	5 0 a. m.	24. 260	52	54			Cirro-stratus	1	West	2	
Camp 29, (5,780′)	July 23	5 0 p. m.	24. 434	84	83	83	58. 5	Nimbus, cumulus	9		0	Rain in mountains.
	July 24	8 0 p. m.	24. 486	65				Cumulus, stratus	7	East	1	
		5 30 a. m.	24. 556	49	50				0	West	0	
		7 0 a. m.	24. 609	62	62. 5	62. 5	54		0	West	1	
		10 0 a. m.	24. 620	71. 5	72. 8	72. 8	57. 5	Cirro-cumulus	1		0	
Camp 30, (6,166′)	July 24	6 30 p. m.	24. 235	70. 3	66. 5	66. 5	51		0	North	1	
	July 25	6 0 a. m.	24. 222	63	64			Cumulus	1	Southwest	2	
		7 15 a. m.	24. 230	67. 3	66. 4			Cumulus	1	N. N. E.	1	
Summit of mount south of Camp 30, (8,607′)	July 25	11 0 a. m.	22. 320	72. 5	75			Cumulus	4	North	1	
Camp 31, (7,423′)	July 25	7 0 p. m.	24. 099	64	59. 5			Cumulus	1		0	
	July 26	6 15 a. m.	24. 047	59	59. 2			Nimbus	9		0	Light rain,
Camp 32, (5,273′)	July 26	2 15 p. m.	24. 956	68. 5	65			Nimbus, cumulus	9		0	Showery.
		6 45 p. m.	24. 962	60. 9	59. 5			Cumulus, cumulo-stratus	1	West	0	
	July 27	5 0 a. m.	25. 048	47. 5	47			Stratus, cumulus	4	Northwest	[illegible]	
		7 0 a. m.	25. 066	56. 5	57			Cumulus	1	West	[illegible]	

TABLE I.—*Meteorological record of Northwest Wyoming expedition from May* 19 *to September* 13, 1873—Continued.

Station.	Date.	Time.	Barometer.	Attached thermometer.	Detached thermometer.	Dry bulb.	Wet bulb.	CLOUDS. Kind.	CLOUDS. Amount.	WIND. Direction.	WIND. Force.	Remarks.
Camp 32	July 27	11 0 a. m.	25.078	70.8	67.5	......	......	Cumulus	3	Southwest	1	
Camp 33, (5,845′)	July 27	6 0 p. m.	24.536	69.1	67	......	......	Cumulus, nimbus	6	......	0	
		7 0 p. m.	24.544	66.5	65.7	......	......	Nimbus, cumulus	9	South	1	Heavy shower to south.
	July 28	7 15 a. m.	24.537	60.3	59.6	......	......	Cumulus	1	South	2	
		11 0 a. m.	24.529	76	68.5	......	......	Cumulus	7	Northeast	1	
Camp 34, (6,042′)	July 28	6 0 p. m.	24.357	71	67	......	......	Cumulus, cirrus, nimbus	7	Northeast	1	
		7 0 p. m.	24.344	58.6	59	......	......	Cumulo-stratus	4	......	0	
	July 29	6 15 a. m.	24.322	52.6	52.5	......	......	Cumulus	1	West	2	
		1 0 p. m.	24.263	79	74.5	......	......	Cumulus	5	West	1	
		2 0 p. m.	24.240	74.4	72	......	......	Cumulus	7	North	2	
		6 0 p. m.	24.203	65.7	64.5	......	......	Cumulus, nimbus	9	North	1	Thunder to north.
	July 30	6 20 a. m.	24.213	53.9	65.5	......	......	Cumulo-stratus	½	West	1	
Camp 35, (6,319′)	July 30	2 0 p. m.	23.800	75	72.3	......	......	Cumulus	5	......	0	
		6 0 p. m.	23.784	66	65.6	......	......	Cumulus, nimbus	8	West	2	Light showers.
	July 31	5 0 a. m.	23.790	35.5	36.5	......	......	......	0	......	0	
		7 0 a. m.	23.818	71.5	56.5	......	......	......	0	West	1	
		10 45 a. m.	23.822	74.6	72.5	......	......	Cumulus	2	West	2	
Camp 36, (6,683′)	July 31	4 35 p. m.	23.500	67.5	66.5	......	......	Cumulus	3	North	1	
		7 0 p. m.	23.492	58	57.4	......	......	Cumulus	1	Northwest	1	
	Aug. 1	4 30 a. m.	23.509	34.2	34	......	......	......	0	......	0	Light dew.
		5 15 a. m.	23.530	33.5	33	......	......	Cirro-cumulus	1	Northwest	1	
Summit of Sailor Mount, (10,046′)	Aug. 1	9 30 a. m.	20.880	61	56	......	......	Cumulus	1	South	1	
		10 0 a. m.	20.893	64.5	58	......	......	Cumulus	2	South	1	
		12 m	20.893	62.7	60	......	......	Cumulus	7	South	1	
Camp 36, (6,683′)	Aug. 2	5 0 a. m.	23.599	34	34	......	......	......	0	North	0	Light frost.
		6 30 a. m.	23.616	35	35.5	......	......	......	0	North	0	Smoky.
Summit of Pass, (9,444′)	Aug. 2	2 0 p. m.	21.340	67	......	......	......	Cumulus	1	West	2	
Camp 37, (8,940′)	Aug. 2	7 45 p. m.	21.786	56.2	......	......	......	......	0	East	0	
	Aug. 3	6 30 a. m.	21.706	44	44.5	......	......	......	0	East	0	
Summit of Pass, (9,444′)	Aug. 3	9 0 a. m.	21.288	60	59.5	......	......	......	0	West	1	
Camp 37, (8,940′)	Aug. 3	12 40 p. m.	21.766	75	67.5	......	......	Cumulus	2	......	0	
		6 0 p. m.	21.709	61	60.6	......	......	Cirrus	1	North	1	Thunder; a few drops rain.
	Aug. 4	5 0 a. m.	21.640	47.5	48.5	......	......	Cirro-cumulus	8	Southeast	1	
		6 30 a. m.	21.648	50.5	52	......	......	Cirro-cumulus	9	......	0	
Camp 38, (7,564′)	Aug. 4	4 0 p. m.	22.692	56.8	56.5	57.5	51.8	Cumulo-stratus	10	Northwest	1	
		7 0 p. m.	22.702	51.2	51.2	53.1	50	Nimbus	10	......	0	Drizzling rain.
	Aug. 5	7 0 a. m.	22.798	48	48.3	51	49	Cumulo-stratus	10	North	0	
		12 m	22.839	63.8	64.1	62.5	55	Cumulus	5	East-southeast	0	Thundering in the north.
		2 0 p. m.	22.848	62.5	62	......	......	Cumulus, nimbus	8	East-southeast	1	

		6 0 p. m.	22.825	61.8	61.8	62.7	54.3	Cumulo-stratus	5		[illegible]	
		9 0 p. m.	22.828	54.5	53.5			Cumulo-stratus	7	West	[illegible]	
	Aug. 6	7 0 a. m.	22.846	51.5	50.5			Cumulus	2	South	0	
		2 0 p. m.	22.838	67.5	66			Cumulus	4	South	0	
		6 0 p. m.	22.794	62.2	62.7	63	50.1	Cumulus	1	Southeast	0	
		9 0 p. m.	22.760	46.5	46.5	48.3	43	Cumulus	2	North	0	
	Aug. 7	7 0 a. m.	22.734	49	47	51.4	46.5		0	South	0	
Camp 39, (7,492′)	Aug. 7	7 0 p. m.	22.701	61.4	53				0		0	
	Aug. 8	6 0 a. m.	22.734	35	37				0		0	
		12 m	22.813	66.5	65				0	South	1	
	Aug. 9	7 0 a. m.	22.851	47.5	40	40	37	Cirro-stratus	1	South	1	
		2 0 p. m.	22.886	67.5	72			Cirro-stratus	9	South	1	
		3 0 p. m.	22.892	72	70.8	70.8	49.5	Cirro-stratus	9	South	1	
		6 15 p. m.	22.870	66	66.5	66.5	50.5	Cirro-stratus	8		0	
	Aug. 10	5 30 a. m.	22.844	33	31.5	31.5	30.5	Cirro-stratus	1		0	Thin layer of ice.
Camp 40, (7,908′)	Aug. 10	6 0 p. m.	22.491	67	62.6	62.6	51.5	Cirro-cumulus	3	West	0	
	Aug. 11	7 0 a. m.	22.484	51.5	52	52	47	Cirro-stratus	3		0	
		2 0 p. m.	22.478	71	68.5	68.5	49	Cirro-stratus	10	Northwest	0	
		6 0 p. m.	22.455	60.2	60.4	60.4	52.5	Cumulo-stratus	10	Northwest	0	
	Aug. 12	5 15 a. m.	22.389	47.6	48.5			Nimbus	10		0	Drizzling.
		2 0 p. m.	22.407	61.5	59.5	59.5	54.5	Cumulus, nimbus	9	West	1	Clearing up.
		7 0 p. m.	22.409	54.7	52.6	52.6	49.5		0		0	
	Aug. 13	6 0 a. m.	22.450	43.1	44			Cumulus	10	East	1	
Camp 41, (5,741′)	Aug. 13	7 20 p. m.	24.283	63	57.1			Cumulo-stratus	1	South	1	
	Aug. 14	9 30 a. m.	24.374	60.5	63.1	63.1	55	Cumulus	9	North	1	
		1 0 p. m.	24.355	67.6	66.5			Cumulus, nimbus	8	North	2	
		2 0 p. m.	24.373	60	59.5	59.5	52.5	Cumulus, nimbus	10	West	3	Threatening.
		6 40 p. m.	24.421	56.8	55	55	51	Cumulo-stratus	1	Northwest	1	Steady rain from 2 to 4 p.m.
	Aug. 15	12 m	24.404	66.2	65			Cirrus, cumulus	2		0	
		6 30 p. m.	24.330	64.5	64.5			Cirrus, cumulo-stratus	9	West	1	
	Aug. 16	6 0 a. m.	24.335	43.5	43.5				0		0	
		2 10 p. m.	24.302	79.5	77	77	61.5	Cumulus	2	West	1	Thunder-shower with hail, 2.30 to 3 p. m.
	Aug. 17	5 30 a. m.	24.342	39.5	39.5				0	Southeast	1	
		10 50 a. m.	24.334	70	67			Cumulus	4		0	
Camp 42, (5,813′)	Aug. 18	7 0 a. m.	24.198	48.8	49.1				0	Southeast	0	
		2 15 p. m.	24.166	81.5	80				0	Northwest	1	
		7 30 p. m.	24.110	56	53.6			Cumulus	1	East	0	
Mount Washburn, (10,105′)	Aug. 19	1 0 p. m.	20.835	64.5				Cumulo-stratus	2	South	3	
Camp 43, (7,724′)	Aug. 19	6 0 p. m.	22.599	62.7	59			Cumulus	2		0	
		7 15 p. m.	22.574	50.5	50.5			Cumulo-stratus	2		0	
	Aug. 20	7 0 a. m.	22.592	48.5	48.5	48.5	44	Cirro-cumulus	1		0	
		2 0 p. m.	22.594	65.5	64	64	46	Cumulo-stratus	6	Southwest	2	
		6 0 p. m.	22.578	63	64	64	51	Cumulo-stratus	2	North	0	
	Aug. 21	7 0 a. m.	22.548	50	39.5	39.5	36		0	Southeast	0	
		7 0 p. m.	22.511	56.1	56.5	56.5	45.8	Stratus	0		0	
Camp 43, (7,724′)	Aug. 22	5 30 a. m.	22.484	40.6	40.2	40.2	38.9	Stratus	10	Northwest	0	
		7 0 a. m.	22.490	46.2	46.0	46.0	42.7	Stratus	10	Northwest	0	
		2 15 p. m.	22.490	56	56.0	56	51	Nimbus	10		0	Drizzling rain.
		6 10 p. m.	22.475	48.8	48	48	48	Cirro-stratus	6		0	
	Aug. 23	7 0 a. m.	22.590	38.5	38.8	38.8	37.8	Cumulo-stratus	9	North	0	
Camp 44, (8,986′)	Aug. 23	6 30 p. m.	22.615	54	53.9				0		0	

TABLE I.—*Meteorological record of Northwest Wyoming expedition from May 19 to September 13, 1873*—Continued.

Station.	Date.	Time.	Barometer.	Attached thermometer.	Detached thermometer.	Dry bulb.	Wet bulb.	CLOUDS. Kind.	CLOUDS. Amount.	WINDS. Direction.	WINDS. Force.	Remarks.
Camp 44	Aug. 24	5 15 a. m.	22. 616	36	38	......	......	Stratus	8	......	0	
Camp 45, (7,132′)	Aug. 25	7 0 a. m.	23. 214	38. 5	37	......	......	Fog	10	West	0	
Camp 46, (7,373′)	Aug. 25	2 0 p. m.	23. 049	71. 1	69. 2	......	......	Cumulus	7	North	1	
	Aug. 26	5 40 a. m.	22. 999	42	41. 5	......	......	Cumulus	3	......	0	
		9 30 a. m.	23. 016	66	65. 8	......	......	Cumulus	2	West	2	
Camp 47, (8,302′)	Aug. 27	5 15 p. m.	22. 253	53. 9	54. 5	......	......	......	0	South	3–4	
Camp 48, (7,[illegible]65′)	Aug. 28	7 0 p. m.	22. 852	50	46. 5	......	......	Cirro-stratus	1	West	1	
	Aug. 29	7 0 a. m.	22. 825	39	34	......	......	......	0	Southwest	1	
		9 45 a. m.	22. 835	58	50	......	......	......	0	Northeast	1	
Camp near base of Mount Sheridan	Aug. 29	6 35 p. m.	22. 560	54	52. 3	52. 3	42	......	0	West	0	
	Aug. 30	5 15 a. m.	22. 556	43	44	......	......	Stratus	1	West	1	
Summit of Mount Sheridan, (10,156′)	Aug. 30	11 0 a. m.	20. 840	64	57	......	......	Cirro-stratus	1	West	1	
		12 m	20. 842	65	60. 4	......	......	Cirro-stratus	1	......	......	
Camp 49, (7,564′)	Aug. 30	7 0 p. m.	22. 840	57	52	......	......	Stratus	4	South	0	
Camp 50, (7,552′)	Aug. 31	9 30 a. m.	22. 859	57. 5	56. 2	......	......	Cirro-stratus	3	East	1	
Camp 51, (7,563′)	Aug. 31	4 0 p. m.	22. 836	69. 5	68. 5	68. 5	53	Cumulus	2	South	1	
		6 0 p. m.	22. 829	63. 5	62	62	52	Cumulo-stratus	8	......	0	
	Sept. 1	6 0 a. m.	22. 773	51	46	......	......	Cumulo-stratus	9	South	3	
Camp 52, (7,788′)	Sept. 1	6 0 p. m.	22. 604	58	50. 5	......	......	Cumulus, nimbus	8	......	0	Threatening rain.
Camp 53, (7,848′)	Sept. 2	7 30 a. m.	22. 558	60. 5	52. 8	......	......	Cirro-cumulus	1	......	0	
	Sept. 3	8 30 a. m.	22. 590	50	45. 6	......	......	Cumulus, nimbus	9	......	0	
Camp 54, (8,081′)	Sept. 3	6 30 p. m.	22. 396	40. 5	36. 6	......	......	Cumulus, nimbus	9	......	0	Drizzling.
	Sept. 4	7 30 a. m.	22. 462	43	44	......	......	Cumulus	7	Northwest	1	Fog on mountains.
		9 0 a. m.	22. 480	46	46	......	......	Cumulus	9	Northwest	0	Do.
Camp 55, (7,575′)	Sept. 4	6 0 p. m.	22. 846	48. 5	45	45	43	Cumulus	7	West	0	
		7 0 p. m.	22. 820	42	41	41	39. 5	Stratus	1	West	1	
	Sept. 5	7 0 a. m.	22. 890	37. 7	34. 5	34. 5	33	Cirro-cumulus	1	North	0	Slight frost.
Camp 56, (6,892′)	Sept. 5	3 0 p. m.	23. 496	64	64	......	......	Cumulus	5	Southwest	1	
		6 30 p. m.	23. 496	50	50	50	46	Cumulus	5	......	0	
	Sept. 6	6 0 a. m.	23. 567	30. 0	32	33	33	Fog	10	......	0	
		8 0 a. m.	23. 580	38. 5	38	38	37. 5	......	0	South	0	
Camp 57, (8,917′)	Sept. 6	6 30 p. m.	21. 884	47. 5	44	......	......	......	......	......	......	
	Sept. 7	7 0 a. m.	21. 809	33	33. 5	33. 5	32	Cirrus, cumulus	4	South	0	
Mountain southwest of pass (10,625′)	Sept. 7	10 35 a. m	20. 568	61	49. 5	......	......	Cumulus	2	......	0	
Togwotee Pass, (9,621′)	Sept. 7	11 30 a. m.	21. 376	62. 1	51. 5	......	......	Cumulus	1	Northwest	1	
Camp 58, (7,498′)	Sept. 7	6 0 p. m.	22. 997	59. 5	53. 8	......	......	Cumulus	0	South	0	
	Sept. 8	6 0 a. m.	22. 980	31	32	......	......	......	0	......	0	
		9 0 a. m.	23. 017	69. 5	62. 5	......	......	Cirro-stratus	1	East	0	
Camp 59, (6,942′)	Sept. 8	6 0 p. m.	23. 536	59	58. 5	58. 5	44. 5	Cirrus, cumulo-stratus	1	......	0	

	Sept. 9	6 0 a. m.	23. 500	42. 5	42. 5	42. 5	36. 5	Cirrus	1	West	1
		7 30 a. m.	23. 518	63. 5	53	53	43. 5	Cirrus	1	West	0
		9 0 a. m.	23. 524	67. 5	66	66	51	Cirrus	1		0
Camp 60, (6,172′)	Sept. 9	6 0 p. m.	24. 120	70. 5	70			Cirro-cumulus	1	West	2
	Sept. 10	6 0 a. m.	24. 105	50. 5	48. 5	48. 5	40. 5		0	West	2
		8 0 a. m.	24. 115	59. 5	59	59	46. 5		0	West	0
		9 0 a. m.	24. 113	66. 7	67	67	51	Cirrus	1	West	1
Camp 61, (5,7[illegible]′)	Sept. 10	6 10 p. m.	24. 392	73	67. 5			Cumulus, stratus	1	West	0
	Sept. 11	7 0 a. m.	24. 438	57	53. 5			Cirro-cumulus	3		0
Camp 62, (5,799′)	Sept. 11	6 15 p. m.	24. 518	64	65. 5			Stratus, cumulus	8	Northwest	1
	Sept. 12	7 0 a. m.	24. 636	57	55. 1				0	West	0
Camp Brown, (5,498′)	Sept. 12	6 0 p. m.	24. 750	67. 5	61						
	Sept. 13	8 0 a. m.	24. 744	58	51. 2	59	49. 6		0		0
		2 0 p. m.	24. 658	78	76	83. 2	56. 1	Cirrus	2	Southwest	1
		6 30 p. m.	24. 634	72	68	67	49	Stratus	2	West	1

TABLE II.—*Record of radiation, maximum and minimum thermometers.*

Station.	Date.	Heat.		Radiation.	
		Max.	Min.	Solar.	Terres-trial.
	1874.				
Fort Bridger	June 9	79.5	61	126.75	58
	June 10	82	29	133	28.5
	June 11	82.5	45.5	142.5	45
	June 12	....	39.5	....	....
Camp 5	June 14	96	....	140.5	....
Camp 6	June 15	115	....	170 (?)	....
Camp 7	June 16	88.5	....	150.7	....
Camp 8	June 18	....	38.5	....	....
Camp 9	June 19	97	45.5	152.5	....
Camp 10	June 20	....	41	148	....
	June 21	90	37	149.25	....
Camp 12	June 23	62	23	....	....
Camp 13	June 24	....	21	....	....
Camp Stambaugh	June 25	78.5	68	....	....
	June 26	83	36	140.75	....
	June 27	83	38	143.8	....
Camp Brown	July 2	82	....	138.6	....
	July 3	83	66	147.2	....
	July 4	86	49	148	....
	July 9	82	50.5	....	....
Camp 26	July 19	....	....	161.25	....
	July 20	....	....	129.5	....
Camp 34	July 29	....	46.5	....	....
Camp 35	July 30	....	44.5	....	....
	July 31	....	36.5	....	....
Camp 36	Aug. 1	....	33	....	....
	Aug. 2	....	34	....	....
Camp 38	Aug. 4	58.5	....	....	....
	Aug. 5	67.8	39.7	....	....
	Aug. 6	69	46	....	....
	Aug. 7	....	37	....	....
Camp 39	Aug. 9	....	22.5	....	....
	Aug. 10	....	30.2	....	....
Camp 40	Aug. 11	....	38.5	....	....
	Aug. 12	....	46.6	....	....
	Aug. 13	....	37	....	....
Camp 41	Aug. 15	....	....	146.5	....
	Aug. 16	....	38.5	....	....
	Aug. 17	....	38	....	....
Camp 42	Aug. 18	....	31	....	....
	Aug. 19	....	35	....	....
Camp 43	Aug. 20	....	32.5	....	....
	Aug. 21	....	26	....	....
	Aug. 22	....	40.2	....	....
	Aug. 23	....	33	....	....
Camp 44	Aug. 24	....	38	....	....
Camp 45	Aug. 25	....	35	....	....
Camp 46	Aug. 26	....	41.5	....	....
Camp 47	Aug. 27	....	48	....	....
	Aug. 28	....	13.5	....	....
Camp 48	Aug. 29	....	24.5	....	....
Camp 49	Aug. 30	....	27	....	....
Camp 50	Aug. 31	....	27.5	....	....
Camp 51	Sept. 1	....	38	....	....
Camp 52	Sept. 2	....	36	....	....
Camp 53	Sept. 3	....	37	....	....
Camp 54	Sept. 4	....	35	....	....
Camp 55	Sept. 5	....	29	....	....
Camp 56	Sept. 6	....	27	....	....
Camp 57	Sept. 7	....	28.5	....	....
Camp 58	Sept. 8	....	26	....	....
Camp 59	Sept. 9	....	42	....	....
Camp 60	Sept. 10	....	46	....	....
Camp 61	Sept. 11	....	46.5	....	....
Camp 62	Sept. 12	....	34.5	....	....
Camp Brown	Sept. 13	78.5	39	....	....

TABLE III.—*Temperature of springs, waters, &c.*

Date.	Time.		Temperature.
1873.			°
June 13	12 0 m.	Sand, on ridge between Big Muddy and Ham's Fork	126
June 19	9 30 a. m.	Sand, on divide between Big and Little Sandy	112
June 19	6 0 a. m.	Water in well at station-house, near Camp 9	36
June 19	6 0 a. m.	Water in Big Sandy	53
June 26	2 0 p. m.	Water in well at Camp Stambaugh	40
June 29	5 0 a. m.	Spring near Camp 15	42
July 21	7 0 p. m.	Spring at Camp 27	44
July 25	2 0 p. m.	Spring near Camp 30	37.5
Aug. 3	6 30 a. m.	Spring at Camp 37	37
Aug. 4	4 0 p. m.	Yellowstone Lake	60.5
Aug. 5	7 0 a. m.	......do	56
Aug. 6	6 0 p. m.	......do	65.5
Aug. 7	6 0 a. m.	......do	58

ASTRONOMICAL REPORT.

BY LIEUT. S. E. BLUNT, *Thirteenth United States Infantry.*

Instruments—Failure of chronometers—Examples of computations.

ENGINEER OFFICE,
Omaha, Neb., January 1, 1874.

SIR: I have the honor to make the following report concerning the astronomical work of the expedition to Northwestern Wyoming during the summer of 1873. The observations were taken by myself, assisted by Mr. George C. Hitt.

The only instruments used were one sextant, one reflecting circle, and one artificial horizon; two box-chronometers, one regulated on mean solar time, and the other on sidereal time, were used in connection with the sextant at Fort Bridger, and part of the way to Camp Stambaugh. The boxes containing the sextant and reflecting circle were carried on the backs of men in the saddle; thus transported, the instruments remained in good order, and, though they were always examined before taking an observation, adjustment was but seldom found necessary. The box-chronometers were also packed in the usual manner for field transportation and carefully carried on the back of a man in the saddle; but it was our experience that the slight motion that they were thus unavoidably exposed to, so impaired their rate as to render them worthless as a means of determining longitude. They were left at Camp Stambaugh, and a pocket-chronometer (Frodsham, 9898) was used during the remainder of the trip, and gave satisfaction; its rate had been determined at Omaha, and also at Camp Brown, before leaving and after returning; all three results closely agreeing.

Longitude at the following places was obtained by means of lunar observations; the distance of the moon from the sun, and also from a planet or star, or from both, being taken.

At Fort Bridger, mean of two lunars; Camp Brown, mean of fourteen lunars; outlet of Yellowstone Lake, mean of four lunars; Camp 49, on Yellowstone Lake, mean of four lunars; Camp 56, on Buffalo Fork of Snake River, mean of three lunars.

Some of the lunars at Camp Brown were taken before departure for the Yellowstone, the remainder after our return—the fourteen observations being taken on four different days.

To show the manner of taking the observations for longitude by lunar distances, and for field-work the closeness of the results obtained, I give the observations at the outlet of Yellowstone Lake, (Camp 38.)

Observations for longitude by lunar distances, moon, Mars. Outlet of Yellowstone Lake, Camp 38, *August* 6, 1873.

Observed double altitude of moon, lower limb.	Observed double altitude of Mars.	Distance of Mars from moon, near limb.	Time of observation noted by watch.	Watch fast of mean solar time.	Mean solar time of observation.	Deduced longitude west of Greenwich in time.
° ′ ″	° ′ ″	° ′ ″	*h. m. s.*	*h. m. s.*	*h. m. s.*	*h. m. s.*
23 14 00	34 43 30	67 47 50	9 41 42.5	1 0 9.5	8 41 33	7 21 25
29 25 30	29 12 40					
29 25 30	29 12 40	67 57 40	10 5 3	1 0 9.5	9 4 53.5	7 21 15.5
30 40 00	23 10 10					
30 40 00	23 10 10	68 4 00	10 18 7	1 0 9.5	9 17 57.5	7 21 35.5
31 58 10	21 57 50					
31 58 10	21 57 50	68 7 10	10 25 32.5	1 0 9.5	9 25 23	7 21 35
32 30 00	20 00 00					

Index error of sextant, 00″. Barometer, 22.824 inches. Error of eccentricity of sextant, 00″. Attached thermometer, 55°.5. Detached thermometer, 54°.5.

The altitudes of the moon were taken at equal intervals before and after the time of observing for distance—the same in regard to Mars; the means of the altitudes thus obtained were used as the altitudes at the time the distance was measured, this being more accurate than any other method that could be adopted by a single observer.

The computations were made according to Chauvenet's method of correcting lunar distances.

Longitudes for other points were determined from the error of the pocket-chronometer on local mean solar time, its error on the mean solar time at Camp Brown being found by computation; lunars serving as checks upon these where the longitude was obtained by both methods, and the two determinations agreeing closely; the longitudes by time can be regarded as close approximations.

The mean solar-time at place of observation was found either from equal altitudes of the sun or of a star; Arcturus, *a Serpentis, a Ophiuchi,* or *a Aquilæ* being generally used.

Latitude was obtained by circum-meridian altitudes of the sun, or of the same stars as used in the observations for time. Whenever the party remained more than one day at the same camp, latitude was determined each noon, as well as by the stars at night. Here, too, very satisfactory results were obtained, remembering that no other instrument but a sextant was used in the observations.

I give one of the observations, and the mean of the deductions from four others, to show how closely the results agree with each other.

Determination of the latitude, from observed double circum-meridian altitudes of the sun. Camp 38, (*outlet of Yellowstone Lake,*) *August* 5, 1873.

Time of observation by watch.	Observed double altitude of sun.	Latitude deduced from each observation.	Remarks.
h. m. s.	° ′ ″	° ′ ″	
0 55 4	123 46 40	44 34 51.26	Barometer 22.803 inches.
58 30.5	52 30	34 57.94	Attached thermometer 65°.
1 1 4	55 30	34 58.30	Detached thermomer 65°.
4 31.5	57 40	34 55.64	Index error of sextant +40″.
6 23.5	57 50	34 55.47	Error of eccentricity of sextant 00″
8 24	57 20	34 53.19	Watch fast of mean solar time, 1h 0m 13s.57.
10 40	55 30	35 00.76	Approximate longitude, 33° 15′ west from Washington.
13 22.5	52 20	35 00.01	Approximate latitude, 44° 34′.
15 42	48 30	34 56.77	

The latitude deduced from the mean of these nine observations on the sun is 44° 34′ 56″.59, and from the other four sets 44° 34′ 47″.2; 44° 34′ 52″.23; 44° 34′ 53″.56, and 44° 34′ 49″.97, respectively, giving a mean for the final result of 44° 34′ 51″.91.

The following is the list of latitudes and longitudes determined:

List of astronomical stations.

Stations.	Latitude.			Longitude.		
	°	′	″	°	′	″
Fort Bridger	41	15	37	110	22	39
Camp No. 8	41	54	36			
Camp No. 10	42	7	43			
Camp Stambaugh	42	29	56	108	48	28
Camp Brown	42	59	11	108	53	51
Camp No. 21	43	12	25	108	57	28
Camp No. 26	43	41	00	108	50	22
Camp No. 28	44	2	30	108	51	22.5
Camp No. 30	44	19	15	109	7	54
Camp No. 32	44	30	16	109	14	4
Camp No. 33	44	28	48	109	30	34
Camp No. 34	44	28	6	109	39	14
Camp No. 35	44	28	11	109	52	13
Camp No. 36	44	33	46	109	59	15
Camp No. 37	44	32	45	110	10	46
Outlet of Yellowstone Lake	44	34	52	110	21	56
Camp No. 42	44	56	13	110	23	30
Old Faithful, (Upper Geyser Basin)	44	28	30	110	53	51
Camp No. 49	44	22	26	110	18	50
Camp No. 55	43	56	47	110	5	20
Camp No. 56	43	51	13	110	9	10
Togwotee Pass	43	46	29	110	00	57
Camp No. 59	43	33	13	109	38	10
Camp No. 60	43	26	45	109	14	36
Camp No. 61	43	17	15	109	2	51

The magnetic variation could not easily be obtained very accurately with the instruments at my command; three or more observations, however, were taken whenever the declination was obtained, in order to eliminate errors as much as possible, and a mean of the results adopted as the final result. They can probably be depended upon to within 5′.

Table of magnetic variations.

Date.	Stations.	Declinations.	
		°	′
June 9	Fort Bridger	17	30
June 17	Camp No. 8	17	30
June 19	Camp No. 10	17	32
June 26	Camp Stambaugh	17	25
July 4	Camp Brown	17	33
August 6	Outlet of Yellowstone Lake	19	1
August 9	Yellowstone Falls	19	0
August 22	do	19	1
August 26	Upper Geyser Basin	19	33
September 6	Camp 56, (Teton Fork, Snake River)	19	6
September 9	Camp 59, Wind River	18	43
September 10	Camp 60, Wind River	18	36
September 11	Camp 61, Wind River	18	27
September 13	Camp Brown	17	35

I am, sir, very respectfully, your obedient servant,

STANHOPE E. BLUNT,
Second Lieutenant Thirteenth Infantry.

Capt. W. A. JONES,
Corps of Engineers.

GEOLOGICAL REPORT.

BY PROF. THEO. B. COMSTOCK.

CHAPTER I.

INTRODUCTION.

Explanation—General plan of geological report—Narrative of special trips.

Before proceeding to the more special and detailed account of the geology of the district traversed by Captain Jones during the summer of 1873, it will be proper to devote a little space to a hasty review of some points connected with the trip itself, which come justly within the scope of this report, and which, if not here introduced, might leave unexplained some matters of greater significance. It is also desirable that some explanation should be given of the causes which have led to the appearance of the report in its present shape.

Upon my return from the field with an abundance of material, in the form of notes and specimens, for the preparation of a report upon the geological structure of the greater portion of the western third of Wyoming Territory, it very soon became evident that the labor of arranging and elaborating completely the whole of the work done in the field would require much more time than could well be allowed me. This difficulty would have been grave enough had the region explored been of no more than ordinary interest; but when the wonderful extent and variety of this section is fully realized and considered, it will be seen that my task has thereby been greatly increased. In addition to this difficulty, circumstances beyond my control have compelled me to work with very few advantages of reference or comparison. As a natural result, regretted by no one more than by the writer, the following pages will be found lacking in several important particulars, among which two interesting subjects require some notice in this place. I refer to paleontology and chemical geology, in both of which departments much material was collected, but which, for the reasons mentioned, have been necessarily treated quite summarily. So far as I have been able, I have identified the fossils collected, and, in most cases, I have thus been enabled to determine with certainty the formations from which they were obtained.

PLAN OF GEOLOGICAL REPORT.

In the preparation of this report I have sought to arrange its component parts in such a manner as to combine utility with conciseness of expression and ease of reference. In a work which is intended merely as a *résumé* of the more important results of field-labors, it is excusable, not to say necessary, that events and discoveries should be narrated in the order of their occurrence, but, however easier it may be to thus send forth the final results, such a report can only be accepted as the forerunner of a more complete and elaborate treatise in the future. Though indulging the hope that the ample material now in my possession may yet yield richer fruit under more favorable circumstances, I have yet felt, in the absence of such assurance, that the present work should have as much of the air of a finished production as can well be given to it within necessary limits. For this reason the plan of arrangement adopted in the following pages is the grouping of facts and conclusions under appropriate heads, with little or no regard to sequence of observation, except when essential to the complete elucidation of any subject. Each broad division of geology and related subjects is discussed in succession, each occupying as many chapters as may be deemed expedient. In each chapter the several prominent topics are plainly indicated by head-lines in the text, and these, with minor topics, will readily be found by referring to the copious index at the close of the report. This method, which, I believe, will prove most satisfactory to the majority of those who will use this report, will necessitate a somewhat more careful attention than would be required by an arrangement which would allow of more frequent repetition; but I am persuaded that if this treatise be incapable of resting upon its own merit, nothing in the way of mere composition can make it any more deserving of generous approval. It has been thought desirable, however, in one or two instances, to give a brief *résumé* or recapitulation of several chapters, as in chapter VI, which is devoted to a general review of local geology, systematic and economical.

The order of arrangement of the several chapters is in a measure natural and progressive. Beginning with a notice of the physical geography, or the resultant of all the various forces which have combined to produce the present surface features, then proceeding to the discussion of geological structure or the resistance encountered, the determination of the forces themselves comes next in order, after which such special subjects as are not directly connected with the geology of the region are considered. To the latter class belong the chapter of archæological notes and the notes upon the Shoshone tribe, with a vocabulary.

NARRATIVE OR ITINERARY OF SPECIAL TRIPS.

It would be entirely superfluous to write anything like a narrative of the occurrences from day to day along the line of march; nor have I thought it necessary to transcribe the greater portion of my field-notes in the form of a journal. I found it necessary, however, upon several occasions, to make independent side-trips for the purpose of obtaining more extended information than was possible at all times in the immediate vicinity of our trail. As the incidents and observations of these sorties will not be elsewhere related, it will be well to describe them without amplification in this place. Each is numbered in the order of its occurrence.

I.—TRIP TO THE UINTAH MOUNTAINS.

June 6.—A delay of several days at Fort Bridger, incident to preparation and organization, afforded an opportunity for a somewhat extended trip, of which I availed myself by a run to the Uintah Mountains for the purpose of observing the structure of that range, and with the intention of learning as much as possible of the intervening country and its geology. I was accompanied by Mr. J. D. Putnam, who carried a mercurial barometer and an aneroid, with which frequent observations were taken. We were piloted by William Somers, a guide of much experience in this section of country. Our route, which was as direct as possible so early in the season, lay across the southwestern corner of the great Green River Basin, in a general south-southeastern direction. When we left the post the water of Black's Fork at that point was unusually high, causing serious damage to bridges, and knowing ones predicted the failure of our little expedition. A ride of eight miles brought us to the crossing of Smith's Fork, which was found to be too high for fording, and we went some distance above, where the creek divides into several smaller streams. Even these proved difficult to cross. One must see these swollen torrents and ford them to fully appreciate their force and the consequent amount of sediment held in suspension. In seasons of heavy floods many of the mountain-streams are veritable rivers in size, and such they are usually named, to the great wonder of those who have seen them only in midsummer, when many are almost dry. All the streams that we were obliged to cross in our progress toward the mountains were very much swollen, and we were not infrequently obliged to cast about for suitable places to ford. After crossing Smith's Fork we bore southward for several miles, passing through a portion of the Grizzly Buttes,* a "bad lands" district now made famous as the scene of the labors of Professors Marsh, Leidy, and Cope, resulting in the discovery of numerous remains of extinct vertebrates. This formation is more or less restricted, flanking the edges of quite extensive benches as a kind of fringe at this point about one mile in width. The buttes are usually capped by grotesque masses of weathered rock in the form of columns or pyramids of various shapes, which often bear a fair resemblance to familiar objects, such as huts, anvils, chimneys, steeples, monuments, nestling birds, &c.

Continuing our course over benches becoming broader and more extended nearer the mountains, we finally reached and crossed Cottonwood Creek, one of a dozen so named within a limited area in the West. From this point we continued our course across sage-brush plains, with little of variety, except an occasional alkali bog, in which our mules sank to their bellies, or an alkali hole, filled with a sloughy mass of the consistency of soft-soap, with irregular streaks of blue and yellow.

Pushing onward rapidly we crossed the divide to the slope toward the west branch of Henry's Fork, camping just at dusk near a fine cold spring, in a sheltered depression upon the hill-side. This camp was at an elevation of about 2,000 feet above the valley of Black's Fork at Fort Bridger, and it was distant by an air-line nearly nineteen miles, and by our course about twenty-two miles from the same point.

June 7.—Left camp quite early, bearing east of south toward the mountains. On our way we encountered quantities of fallen timber, which very seriously impeded our progress. Between two wide belts of this we were obliged to climb a steep bluff strewn with bowlders, largely of red sandstone, but with a beautiful grassy summit almost level. Passing through a narrow opening in the timber which skirts this ridge there is brought to view an inclosed pasture of several acres, evidently a favorite resort of the elk, judging from the number of shed antlers which lie strewn over its surface. The view from this point is very fine, and quite extensive. The ridge slopes rather abruptly upon both sides to the streams below, one of which ripples through a grassy bottom, apparently walled in upon all sides, with a narrow gap where the water

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* In a paper entitled "On the Geology of Western Wyoming," published in the American Journal of Science and Arts, vol. VI, December, 1873, I have offered an explanation of the origin of this name, which proves to be erroneous. Judge W. A. Carter states that the name originated from a report that an old hunter had there discovered a petrified grizzly.

flows out. This was pointed out by our guide as one of his favorite places for wintering stock. Beyond this we passed through an extensive tract of fallen timber, part of it scattered over the surface of a hill which we descended to reach the valley of a small creek to which I have given the name of Bog Creek, merely for convenience of reference. The left bank of this stream for several miles has a very gentle slope toward the creek, and it is, therefore, very boggy and dotted with standing pools, at least early in the season. The slope upon the right bank is very much greater and the bulk of the stream flows along that side of the valley. Passing up the stream by a gradual ascent we suddenly reached a small belt of timber stretching across the valley. This was but a few rods in width, and very quickly the water was found running off rapidly in the opposite direction by a series of small cascades, extending nearly to the junction of the west branch of Henry's Fork, not a great distance below.

The west branch, or Burns' Fork, runs through a broad alluvial valley, very irregularly, frequently, as at this point, splitting into four or five parts, which again unite and separate indefinitely, causing constant changes in the channels by the formation and destruction of islands, peninsulas, ponds, &c. This valley is in many respects the counterpart of the Lower Amazon, but on a very small scale. Even the fluctuations of level caused by the tides in the mighty Brazilian stream, which I have observed at a distance of five hundred miles from the Atlantic coast, are simulated in this average mountain-stream in the rise and fall produced by the alternate melting and freezing of the snows.

Directly opposite our point of approach a side valley opens, but its stream, hugging the right bank, enters Burns' Fork some rods below. Crossing the latter, we ascended this tributary. The upper portion of the valley was very miry, and we were soon in the midst of immense drifts of the slowly-melting snows. For at least two miles our mules fairly floundered, sinking above their knees at almost every step, until we finally reached a high hill covered with loose bowlders, which we ascended by a very steep course to a height of about 4,000 feet above Fort Bridger. Descending upon the other side, a still greater slope, not less than 1,000 feet in height, we reached the main stream of Henry's Fork, which here runs through a comparatively narrow gorge. It was my original intention, after crossing, to push on as far as good forage existed, and there leaving the mules in charge of the guide, to proceed with Mr. Putnam to make the ascent of Gilbert's Peak, one of the most accessible elevations, with an altitude of 13,250 feet. To accomplish this I soon saw was impossible; for the swollen creek, with its fierce current, was rapidly rising, and we dared not attempt its passage. Indeed, we had barely time to kindle a fire and partake of a hasty meal ere we were forced to climb the hill by the flooding of the narrow valley. Baffled in our purpose, we could only make up for our disappointment by returning by a different route. We retraced our steps, however, with little divergence until we reached the valley of West Branch, which we crossed, camping near the entrance of the Cascade Creek before mentioned.

Game in great variety is plentiful in this section; deer, elk, bear, and grouse of several kinds being quite common, particularly in the neighborhood of Burns' Fork, while antelope, and some varieties of grouse, frequent the grassy benches nearer the plains. While at this camp a large drove of elk came very near to feed upon the rich grassy bottom, and all of the game in this vicinity seemed remarkably tame.

June 8.—We crossed the low divide to Bog Creek, following it down near its junction with one of the forks of Sage Creek, to which I will refer under the name of Meadow Brook. Bog Creek Valley continued swampy upon its left bank, widening gradually until we left it, when it descended more rapidly from 50 to 100 feet into the terraced valley of Sage Creek. Crossing the latter, we bore northwest for several miles, gradually veering to the north and northeast, crossing benches, descending as by an irregular succession of steps, until we reached our camp at Fort Bridger. A short distance beyond Sage Creek we came upon a small camp of friendly Ute Indians returning to their reservation from a visit to Fort Bridger for trading purposes. We found our party in Camp 2, having been driven from Camp 1, on lower ground, by the overflow of the stream during our absence. The whole distance traveled upon this trip was not far from one hundred miles.

II.—RED CAÑON ROAD ALONG DEEP CREEK.

June 29.—Just beyond Camp 15, on Twin Creek, the road forks; one branch, called the Red Cañon road, passing by a very steep hill down into the narrow valley of Deep Creek, while the other follows a monoclinal valley farther from the mountains, which leads by a more direct course to the crossing of the Little Popo-Agie near Murphy's Ranch. The train took the latter route, and I followed the former with a small escort. Deep Creek flows through a narrow valley or cañon, originally a monoclinal valley, bounded upon one side by a carboniferous ridge with precipitous bluffs of Triassic red sandstone upon the right, probably extending upward into conformable beds of Jurassic sandstone of a lighter color. The whole valley, for a considerable height, has been filled in with red drift material, through which the stream has cut nearly to the base, leaving a series of terraces high up on the ridges. The name appropriately refers to the manner in which the present stream has cut through its bed; for in some places the narrow creek runs through a gorge with almost vertical sides, at least 20 feet in height, making a veritable cañon in the soft material of the drift, a form of erosion which is somewhat peculiar under such circumstances.

This valley lies very favorably for irrigation, as it receives several fine streams from the mountain-side of the cañon, where the descent is rather gradual. Several fine gardens are here tilled, affording a choice and varied supply of "truck" for consumption at Camp Stambaugh, Miner's Delight, and the settlements in the vicinity of South Pass. Six or seven miles below its source, Deep Creek joins the Little Popo-Agie, almost at a right-angle, just beyond the point at which the latter emerges, with considerable force, from a grand old cañon cut through the limestone ridge. From this point we followed down the left bank of the Little Popo-Agie River to Murphy's, where the main party joined us, and made Camp 16. The valley of the river, as it may be styled, pursues a nearly straight course away from the mountains until it reaches a point below Murphy's Ranch, when it is deflected greatly to the left for some distance, cutting diagonally through the next ridge. This, and other interesting features of these streams, have a peculiar interest to the student of dynamical geology, and they will be further considered in connection with that subject in another chapter.

III.—TRIP TO NUCLEUS OF WIND RIVER MOUNTAINS FROM CAMP BROWN.

July 5–8.—Left Camp 18, at Camp Brown, with Doctor Parry, Messrs. Le Hardy, Putnam, and Jewett, and Somers, my own object being the study of the structure of the range at this point from nucleus to exterior. As in all other cases, I give here only the incidents and general observations of the trip, reserving for future chapters the discussion of geological structure and topics of a special nature. At the kind suggestion of Doctor Irwin, the much-esteemed and highly-successful Indian agent of the eastern Shoshone reservation, we directed our course toward a prominent land-mark in the nucleus known in the neighborhood as Chimney Rock. Passing for five miles over a comparatively level tract, with abundant evidence of ancient glacial action, we followed a well-worn wood-choppers' road, which led us upward for three-quarters of a mile over the regular surface of a ridge of carboniferous limestone with a slope of 20°, (1,900 feet to a mile.) From the top of this we descended several hundred feet only to climb another ridge of older rocks, and so on, ridge after ridge, until the last (*i. e.*, the earliest formed) exposures of the unchanged sedimentary rocks had been passed, when we struck through the metamorphic series, and thence into the granitic nucleus. We were fortunate enough to find our way into a magnificent park, which afforded fine pasturage for our mules, which we rode as far as practicable, leaving them at our second camp to make the ascent of the ridge on foot. This feat proved much more tedious and difficult than we had anticipated, though it was accomplished in a shorter time than we had supposed possible. Mr. Le Hardy and myself left the camp toward evening, hoping to reach a point half way up the first ridge before dark; but we were much surprised to find that the distance to the summit was less than estimated from below, so that we were able to build our signal-fire just at dark, near the edge of the timber-line, at an altitude of 10,500 feet. The first part of our way lay for a short distance through a treacherous bog, partly covered with icy-cold water, which, safely crossed, gave place to a long stretch of huge granite bowlders irregularly tumbled together, making it necessary to make steps of unequal lengths, occasionally leaping, now up, now down, in places where a misstep was of serious consequence. Oftentimes it became necessary to force our way through dense thickets of small but springy undergrowth, reminding one strongly of the impenetrable laurel-brakes of the Alleghanies. After this experience, the long steep climb, through a forest strewn with the dead pine-needles, rendering a sure footing all but impossible, was welcomed as a pleasant variety. This was succeeded by a long, perilous stretch of melting snow, in huge drifts, covering quantities of bowlders, ready at any moment to start from their places and go hurling down the almost vertical declivity thousands of feet into one of those clear, cold lakes that are to be found only in these far-off mountain-fastnesses. It was impossible to climb directly up this slope, and we were obliged to pursue a long diagonal course to the summit. Finally, we passed beyond the snow, continuing our course over less dangerous but not less tiresome bowlders, until we had reached a point several hundred feet above the timber-line, where there grew some small patches of straggling cedars. Here we kindled a roaring fire, and spent the night. Next morning very early we pushed on and succeeded in reaching the "chimney" before the mist had completely obscured the surrounding country. The summit of this isolated mass of rock can only be reached by climbing in the rear to a narrow cavernous opening well toward the top, through which it is necessary to crawl, or, more properly, to drag one's self. The front of this is a very narrow ledge, more than 500 feet from the *débris* below, which leads to a series of rough, irregular steps by which the top can be gained with caution. From this point, 11,853 feet above the level of the sea, we obtained a view of the whole country north and east of the mountains for a distance of one hundred and fifty miles. In front lay the Owl Creek Mountains, with the Wind River like a thread between, and far in the background the Big Horn range with its prominent peaks towering high in air. To the north the Sierra Shoshone and the extension of the Rocky Mountain divide appeared to meet, and no doubt we saw many high peaks far beyond, which seemed to form portions of one of these chains.

The return-trip was but a repetition of the experiences already narrated, with the addition of much discomfort arising from the short supply of provisions, which gave out before we started backward. The total distance traveled was about thirty-five miles.

IV.—TO WASHAKIE NEEDLES, SIERRA SHOSHONEE.

Long before reaching the Owl Creek Mountains we had in view what appeared like a double peak lying beyond, and rising much higher than the main crest of that range, and this assumed so much importance in the topography and geology of the country that a party was organized under the direction of Captain Jones for the purpose of visiting it. Though one of the most interesting excursions made during the trip, there is no call for description here, as it will be given in the general report of the expedition. We left Camp 26 on the 18th of July, traveling in all more than sixty miles, and returning July 20. The peak was ascended to a greater or less height by each member of the party, the highest point reached being over 12,000 feet above sea-level. The geological results of this excursion will be found in the recapitulatory chapter on the general geology of the whole trip.

V.—TO STEAMBOAT SPRINGS, ON YELLOWSTONE LAKE, ETC.

August 6.—From Camp 38, at the outlet of Yellowstone Lake, I went alone to Steamboat Springs, an interesting locality upon the lake-shore, about three miles above the mouth of Pelican Creek. In order to make much headway in this vicinity it is necessary to follow, as closely as possible, in most cases, the lake shore or the valleys of the larger streams. By crossing the marshy valley of Pelican Creek rather near its mouth and crossing a wide belt of fallen timber, I saved two or three miles in the distance by the usual trail, but the time occupied in reaching my destination was largely increased. The groups of hot and cold springs at Steam Point and in the neighborhood are rather numerous, but many of them are very insignificant when compared with those in other localities. Like nearly all of the groups within the Yellowstone Park, however, they present peculiar and distinctive features of their own. Among these none is more interesting than the Steamboat, the noise of which so closely resembles the puffing of a small lake-steamer that one involuntarily casts a longing eye over the surface of the water in the hope that such is really there. This sound is produced by the escape of vapor, under pressure, from a small orifice in a cavernous opening in the rocks. A short distance beyond the vapor issues from a kind of cavern near the water's edge, with a seething sound as it comes in contact with the waves, and this adds greatly to the effect, simulating very closely the escape of waste-steam from a boiler on a windy day.

My work at the springs was completed by 4 o'clock, when I endeavored to pass in a straight course to a point on Pelican Creek, several miles above its mouth, but I was so delayed by the fallen timber that I was barely able to reach a favorable camping-spot on Sulphur Pond, not more than two miles in a direct line from Steam Point, before night set in. I selected a delightful place at the edge of a small grove of trees near the mouth of the eastern inlet of the pond. My camp was upon a well-worn game-trail, which led up a bluff within a few feet of the fire. Being much fatigued, I turned in early, but, when fairly in a doze, I was aroused by the frightened movements of my mule picketed near by, and I presently heard the doleful howl of a large wolf, which was slowly approaching along the trail. In anticipation of a trifling adventure, I lay down again with my carbine close at hand. It was late in the morning when I woke, and all was quiet; but a little investigation showed that the animal had been lying in the grass at the edge of the bluff, just above my head. This locality seems to be a favorite resort of many animals. Our train approached it by following a prominent game-trail, at least a dozen of which, extending for miles into the forest, meet at this point. Upon my first visit to this place, the day before the passage of the train, fresh tracks and other unmistakable signs of their presence were visible. To-day I started numbers of elk while passing through the fallen timber, not far from some active boiling springs. This is probably explained by the fact that there are here a number of cold springs containing sodium chloride, or common salt.

During the night a very heavy mist enveloped the pond like a cloud. It was quickly dispelled by the heat of the sun in the morning.

August 7.—Followed up the small creek near camp for two miles and attempted to cross the divide to Pelican Creek, but I was obliged to return nearly to last night's camp, on account of a comparatively narrow belt of fallen timber, which baffled my utmost endeavors to pass. Nearly the whole of the summit of the ridge was blocked by long windrows of blasted pines, not infrequently forming impenetrable walls four or five feet in height. Reaching the valley of Pelican Creek, I ascended the stream for two or three miles, then crossing, returned, taking Hayden's so-called Sulphur Hills and the hot springs of Lower Pelican Creek on the way. Arriving at Camp 38, and finding it deserted, I followed the trail to Camp 39, which I reached soon after dark.

VI.—FROM CAMP 40 BACK TO CAMP 38, THENCE UP PELICAN CREEK AND DOWN EAST FORK TO CAMP 41.

August 12.—Discovering, while at Camp 46, that a necessary portion of my outfit had been placed in a *cache* at Camp 38 during my absence, I determined to return for it, extending my trip so as to reach the next camp of the main party by a circuitous route. With Mr. Creary as an assistant, I followed back upon our trail as rapidly as possible to Camp 38, at the outlet of Yellowstone Lake, securing my goods, and camping in a grassy spot upon the bank of the river. As we emerged from the timber into the open space about Camp 39, a badger, (*Taxidea Americana* Waterh.,) unwittingly approached quite near to us, but I did not succeed in killing it, although I fired twice at it. About 1 p. m. we stopped for lunch nearly opposite a group of hot springs, about seven miles below Yellowstone Lake, upon the west bank of Yellowstone River. Here Mr. Creary shot with a Colt's revolver a fine male of *Erithizon epixanthus* Brandt, commonly known as the yellow-haired porcupine, of which I obtained the skull and some of the quills. From the size of the testicles, and the presence of a peculiar white, soft, waxy secretion on the exterior of the urinary orifice, as well as the strong skunky odor of the animal, I judge that it was at the beginning of the rutting season. It was also remarkably fat. When shot it was lying in the crotch of a tree, about 10 feet above the ground. Some of our Indians, who were then encamped upon the opposite side of the river, were rejoiced at the gift of the offensive carcass; Luisant remarking that it was "*Heap good eat.*"

August 13.—Left camp early, making a short cut through the timber to Pelican Creek, which we followed up along the right bank for several miles, until, when near some hot springs, at the junction of two of its forks, we struck a prominent trail, evidently that of Doctor Hayden's party of 1871. This we followed for a number of miles, but left it before crossing the divide, choosing another route which led us over the ridge in another place. After struggling through much fallen timber we again struck the trail upon the other slope of the divide, near the point at which it makes an abrupt descent to a tributary of the East Fork of the Yellowstone. From the forks of Pelican Creek the trail leads rapidly upward, passing a series of cascades with one interesting waterfall, the valley for the most part being rather broad and grassy. Plentiful tracks of game were noticed, but we saw very little until near the summit, when we met a large drove of elk and some deer. After reaching the south branch of the East Fork, our course lay through a belt of fallen timber, all but impassable for some distance, when we succeeded in keeping clear of the greatest difficulties by following the most open of the very numerous game-trails high above the stream. By this means, however, we passed unawares the junction of the north and south branches, at which point I had proposed to camp for the night. It had been raining hard all day, and we camped at dark in the mud near a mountain torrent in the midst of a dense forest, our exhausted animals refusing to proceed farther.

August 14.—Continuing our course, four miles of excessively difficult travel through marshes with tangled undergrowth and fallen timber, brought us opposite the mouth of Soda Butte Creek, where we met the well-traveled miners' trail leading to the mining district of Clarke's Fork of the Yellowstone. Beyond this point our ride of nine miles to Camp 41 was comparatively easy. This we reached at 3 p. m., having traveled, since leaving Camp 40, about seventy-five miles.

VII.—FROM CAMP 41, ON EAST FORK OF YELLOWSTONE, TO GARDINER'S RIVER HOT-SPRINGS, AND RETURN.

This excursion, though made independently of Captain Jones's party, was practically over the same ground, and, therefore, requires but little attention here.

August 15.—Left Camp 41, with Mr. Creary, and crossed the bridge over the Yellowstone River. At the foot of a steep hill, which we ascended, about a mile beyond the bridge, three fair-sized California raccoons (*Procyon hermandez*, Wagler,) crossed our path. This neighborhood seems to be well supplied with these animals, as I noticed others at points not far distant. We reached the falls upon the East Branch of Gardiner's River soon after 1 o'clock. I spent the greater part of the afternoon in the examination of the structure between this point and the springs, reaching Captain Jones's camp, near the latter, toward evening.

August 16.—Spent the whole day in the study of the springs, leaving our camp upon the return about 5 p. m. Being very anxious to gain time, we rode the whole distance back to Camp 41 the same night, reaching it soon after 11 p. m., being obliged to move upon a walk on account of the darkness and the fragile nature of the specimens which I had collected.

VIII.—FROM CAMP 42, ON YELLOWSTONE RIVER, TO HELL-ROARING CREEK, THENCE BACKWARD TO AMETHYST MOUNTAIN, RETURNING TO CAMP 43.

August 19.—With Mr. Creary as assistant, I went back from Camp 42, crossing East Fork just above Camp 41. Here we found a trail which led us, by a very direct course, to Hell-Roaring Creek, one mile above its junction with the Yellowstone. On the way we met with several large droves of antelopes feeding upon the fine pasturage here afforded with much security, owing to the irregular topography, which enables them to seek immediate shelter upon the approach of danger. At the time of our visit the great antelope country along the left bank of East Fork was remarkably free from their presence, which may doubtless be explained by the recent passage of several parties of miners. Near the mouth of Hell-Roaring Creek we met another raccoon, which quite savagely resisted an attack until it was forced to beat a hasty retreat. After spending the greater portion of the day in the study of the geology of this section, we returned to East Fork to camp, reaching a favorable spot opposite Camp 41 long after dark.

August 20.—Crossed East Fork, and followed the miners' trail up along the left bank of the river to Amethyst Mountain, which we ascended nearly to the summit, collecting a number of fine mineral specimens, and returning to Camp 42, where we found a small guard in charge of supplies left behind by the train. We proceeded to Tower Creek and spent the remainder of the day in its examination, camping in its cañon for the night.

August 21.—Left camp quite late in the morning, and followed the trail over Mount Washburn to Camp 43, on Cascade Creek, where I packed my collections and prepared for an advance movement on the following day.

IX.—FROM CAMP 43 VIA GEYSER BASINS TO CAMP 47.

August 22.—In order to gain as much time as possible for investigation among the geysers of the headwaters of Madison River, I pushed ahead of the train with Mr. Creary, in a drizzling rain, which continued with occasional heavy showers throughout the day. The route followed was mainly that taken by the train during the following days. Our first camp was in the vicinity of a few prominent silica springs or jets, near the point chosen by the main party next day as Camp 44. Owing to the storm, we did not reach our destination until nearly dark.

August 23.—Took notes and collected specimens from the springs, starting forward at 8 a. m. Passed an area of sulphur jets, and soon struck the old trail of Captain Barlow, (1871,) leading over the divide to a branch of East Fork of Madison River. We then left the trail, crossing the stream much above Barlow's Ford, and striking across the country in a nearly direct line to East Fork, crossing the latter twice via Barlow's trail. After a hasty review of the springs and geysers of the East Fork we visited the lower geyser basin of Fire-Hole River, camping toward its upper end, near the White Dome Geyser.

August 24.—Visited the springs and geysers not previously examined.

About noon we hastened by a short cut through the timber to the Upper Geyser Basin, examining the intervening springs by the way. Camped near the lower end of Upper Basin.

August 25.—Pushed on very early to the upper end of the basin, leaving heavy articles near the spot designated as Camp 46. With my assistant the whole day was spent in a careful study of the principal geysers, until too dark to work.

August 26.—Remained in the Upper Basin until 5.30 p. m., the train having moved on to Camp 47. Rode until after dark, when we picked our way for two or three miles on foot, leading our mules until we could no longer *feel* the trail, and were finally compelled to camp about 9 miles from Camp 46.

August 27.—Moved on at daybreak nine miles to Camp 47, reaching it just in time for a late breakfast.

X.—FROM CAMP 48 TO MOUNT SHERIDAN, THENCE TO CAMP 50.

On this trip I made one of a small party led by Captain Jones from Camp 48, at the southwestern extremity of Yellowstone Lake, to Mount Sheridan, a prominent elevation near the sources of Snake River. We left camp August 29, reaching a camping-spot in the vicinity of some hot springs at the base of the mountain, about 3 p. m. The ascent of the peak was made by all but myself on the following day. With considerable difficulty I succeeded in reaching a prominent point, several hundred feet below the summit, when I was forced to relinquish an attempt which had been made against the advice of my friends, on account of previous over-exertion.

The total distance traveled by myself in these ten excursions, exclusive of that portion over the trail of the main party, was very nearly four hundred miles.

CHAPTER II.

PHYSICAL GEOGRAPHY.

General surface features—mountains—plateaus or table-lands—river-systems.

While it is true that the examination of the minute topography of a country, the contour and forms of relief of its surface, falls somewhat out of the domain of the geologist engaged in the study of the past history of the earth, it is evident that a thorough appreciation of the causes which have produced the present external configuration of our globe is only possible after study of the results. In other words, we have no means of judging of the past except by comparison with the present. It becomes necessary, therefore, at the outset, to devote a little space to a consideration of some of the results of the action of natural forces over the area embraced by our reconnaissance. Moreover, the physical geography of any portion of the earth's surface is closely related to its geology, and it is consequently necessary to examine, with some degree of care, the external features before proceeding to the investigation of internal structure. A full discussion of this subject in all its bearings would, however, lead to encroachment upon the field of others engaged upon the survey, and it is only intended in this chapter to refer to those features which bear more or less directly upon the solution of questions concerning the geology of the district.

Few Americans at the present day are so ignorant of the general topography of their country as not to know that the approach to the central portion of the Rocky Mountain chain from the east is very gradual in most places, but it is very doubtful whether this fact is fully realized by those who have never visited this region, and yet the traveler in the West, unless he be provided with a list of elevations of the principal points, would scarcely be prepared to acknowledge that in passing westward from Omaha to a distance of five hundred miles he had reached an altitude of 5,000 feet above his starting-point, while apparently traversing a level prairie. Southward, along the line of the Kansas Pacific Railroad, the slope is even less, averaging little more than eight feet per mile, while northward, near the latitude of Saint Paul, Minn., it is not more than two feet to the mile.

The ridges of the Rocky Mountain system, considered separately, appear to trend quite irregularly, as if all attempts to arrange them into a general system would prove futile, but when viewed as parts only of a vast whole they are all seen to be subordinate ranges of a great system or chain, with an average northwest-southeast trend.

The district comprising the field of our labors during the summer of 1873 is included between the forty-first and forty-fifth parallels, and the meridians of 108° 14′ west and 111° west. The whole of this tract is within the limits of the two counties of Uintah and Sweetwater, in the western third of the present Territory of Wyoming. For our purpose, though not strictly correct, on account of the convergence of the meridians northward, it may be considered in outline a parallelogram with a length of two hundred and seventy-eight miles, and a width of one hundred and thirty-nine miles. By reference to the topographical map it will, then, be seen that the parallel of 43° north divides this district into two equal squares, each containing 19,300 square miles, the northern division containing the bulk of the mountain-masses, while the southern square is proportionately free from extreme elevation, being mainly occupied by a continuous plateau. Again, if the diagonal from the northwest to the southeast corner of the parallelogram be drawn, it will be noticed that the greater portion of the mountainous country lies within the limits of the northeastern half. The central meridian of this tract (109° 37′ west) cuts the northern square into two such halves that the western portion contains the bulk of the westward, or Pacific-bound waters, and the eastern half contains the greater portion of the Atlantic-bound streams within the district, but each half also contains a certain amount (about equal in each) of the headwaters of rivers belonging to the opposite slope. This latter feature is somewhat remarkable from the fact that it is caused not so much by the distribution of the mountain-masses, as by the operation of apparently insignificant forces, which have produced extraordinary results. In the southern square but a small proportion of the precipitated moisture is carried off by way of the eastern slope, although less is carried westward than might be imagined from the examination of an orographical chart of this region.

ROCKY MOUNTAIN SYSTEM.

The whole of this district may be said to constitute a portion of the great Rocky Mountain chain, as generally understood, although, geologically, this term cannot properly be applied so loosely, because it would imply that over this area all the secondary ranges belong to a single system of upheaval; that is to say, from such a term one might justly infer that the whole tract was occupied by those mountains only which were simultaneously elevated, which is not the case. It will, however, be convenient to use the name in this sense, and chiefly because the only portions of other determined systems which lie within this area are upon its borders, and have not received as much attention as the remaining ranges from the members of our survey. The main crest of the Rocky Mountain system, strictly speaking, passes tortuously across our field, in some places so nearly upon a level with the surrounding country that its true course has only been determined after extended and laborious study upon the part of many explorers; at other points rising abruptly from the plains to a lofty height, with prominent peaks towering high above the mass of the chain. The eastern slope is so gradual that the irregularities of the crest are rendered much more noticeable than similar variations in chains, such as the Appalachian, which rise quite abruptly from base to summit, and at the same time these variations are in reality more extensive. This is one reason that names of purely local application are so common among the western mountains, being almost necessary in order to avoid difficulties which would arise from the confusion of the main divide with ranges which, though more conspicuous, may afterward prove to be subordinate to it, or even of another system. A glance at any ordinary map of Western North America will show the force of these remarks, and their application is perhaps nowhere more manifest than in the section of country now under consideration.

The Rocky Mountain crest has been traced and mapped with considerable accuracy throughout the greater part of its winding course through the territory of the United States, from the thirty-fifth to the forty-ninth parallel. The general direction of the axis of the chain, northward from the thirty-fifth to the forty-first parallel, is nearly north, but at this point it bends gradually to the west until South Pass is reached, in latitude 42° 25′ north, longitude 109° 43′ west, when it is continued northwest in the Wind River Mountains, beyond which it follows a flexuous course, crossing the forty-ninth parallel ten degrees of longitude west of its intersection with the thirty-fifth parallel.

The elevations of passes through the crest vary greatly throughout its length; Vermillion Pass, in British America, having an altitude of less than 5,000 feet, while in Colorado the pass between Gray's and Parry's Peaks is reported by Whitney to be 13,623 feet above sea-level, which is higher than any recorded *peak* of the divide in Wyoming or Montana. The point of greatest elevation in the Rocky Mountain crest within the limits of this survey is Fremont's Peak, of the Wind River Mountains, with an altitude of 13,570 feet.

OTHER RANGES AND SECONDARY RIDGES.

The Wahsatch range and the Uintah Mountains belong, geologically speaking, to a different period of upheaval to that in which the eastern ranges were elevated, a conclusion first adopted by Prof. J. D. Whitney, of the California survey, with respect to the Sierra Nevada range, which was synchronously thrown up, and afterward extended to the Wahsatch and its parallel ranges with their connected ridges, by Prof. Clarence King, in charge of the survey along the line of the fortieth parallel. Very little more than the foot-hills or outlying ridges of either the Wahsatch or the Uintah ranges lies within the district comprising our field, but the relations of both to the geology of this region are so close and important that a general review of their features will be useful.

The Wahsatch Mountains form the boundary between the so-called Great Basin and the basin of the Green River, including the upper portion of the valley of the Colorado. The basin of the Green and Colorado Rivers is divided into two parts by the prolongation eastward, near the forty-first parallel, of the Uintah Mountains. The upper portion of this basin (*i. e.* the portion north of the Uintah Mountains) is commonly called the Green River Basin, and the southern portion has received the name of Uintah Basin. Rising abrubtly from the plains, the Wahsatch Mountains stand out prominently in the topography of the country, although their elevation above the Green River Basin is comparatively small in amount. The culmination of the crest is, however, south of the forty-first parallel in Central Utah. A peculiar ruggedness is produced by the deep-cut cañons which abound, not infrequently extending nearly or quite down to the base of the mountains, which is but little above 4,000 feet in many places at the foot of the western slope. The Union Pacific Railroad in its course through this range, along the cañons of Bear and Weber Rivers, nowhere reaches an elevation as much as 1,750 feet above its crossing of Green River.

The Uintahs present much the same general features as the Wahsatch Mountains, but with less of ruggedness in outline, owing partly to the existence of fewer and less eroded cañons, but principally to the trend of the range and its consequent structure. It should be explained that the Wahsatch chain runs north and south with a series of parallel ridges separated by synclinal valleys, while the Uintah range trending at a right angle forms one immense anticlinal extending across a basin which sheds its water southward. This fact, to a student of dynamical geology, is alone sufficient to account for a very large portion of the existing topography. In the Uintah range there are several peaks with elevations above 13,000 feet, and the greater portion of the crest rises certainly above 11,000 feet. The altitude given by Clarence King for Mounts Hodges and Tohkwano is 13,500 feet, and Gilbert's Peak, according to the same authority, has an altitude of 13,250 feet.

Among the secondary ridges lying directly in our line of march, the Sierra Shoshone and Owl Creek ranges are the most important.

The Sierra Shoshone in its present aspect can scarcely be termed a range of mountains, being more properly an irregular mass of elevated territory, longer than broad, with a succession of isolated points appearing above the general surface in irregular curves. The causes which have produced this configuration have operated since the original formation of a range which is now greatly obscured. Remnants of this partly obliterated range are to be seen in some localities, but in most places it is entirely concealed by a thick formation of volcanic material subsequently deposited. Several imperfect prolongations of the underlying range seem to stretch southward across the upper portion of the valley of Wind River, even in one or two instances extending quite to the foot-hills of the Wind River Mountains. This subject constitutes, however, one of the most important structural problems of the trip, and as such it will be more fully treated under the head of dynamical geology in the section upon the elevation of mountain-ranges.

In physical features, there are some points of resemblance between this Sierra and the Wahsatch chain, but the comparison must not be extended too far, for the similarity is less real than might be imagined from the perusal of finely-wrought descriptions of the scenery, which is, indeed, impressive and remarkable. A comparison of any well-executed map of the region traversed by the Wahsatch chain with the topographical map of Captain Jones will render this more evident. Unlike the chain of the Wahsatch, the Sierra Shoshone, though not a simple anticlinal, has no prominent series of folds which would cause the cañons to be cut through the mass, more or less, longitudinally, but the streams follow the general slope nearly transverse to the length of the Sierra, but with a very irregular northward tendency. The whole area is, to the last degree, rugged, and scored by numerous deeply-cut gorges and cañons.

From the southeastern portion of the area occupied by the Sierra Shoshone the Owl Creek range extends eastward as far as the Big Horn River. This ridge is much less elevated and generally more regular in outline than any of the preceding, although it is not unlike the Uintahs in some respects. The highest point is but little more than 9,000 feet above sea-level, while in the Sierra Shoshone many peaks exceed 10,000 feet, and Washakie Needles, a high point north of the junction with the Owl Creek range, attains an altitude greater than 12,000 feet.

Besides the foregoing there are several other ridges of more or less importance which require at least a passing notice. These are:

1. The Téton range, a most jagged and apparently inaccessible ridge, with a nearly meridional trend, lying in longitude 110° 48′ west. This culminates in a peak known as the Grand Téton, which is the highest point within the limits of our parallelogram. Messrs. Langford and Stevenson, of the Snake River division of Doctor Hayden's party of 1872, report that they ascended to the summit, 13,858 feet above the sea.

2. The Wyoming Mountains, a transverse range, trending latitudinally almost along the line of the parallel of 43° 30′ north, west of the main divide of the Rocky Mountains. This ridge is sometimes called the Green River Mountains.

3. The Sweetwater Mountains, lying east of South Pass and trending eastward from that point.

4. Far to the northeast lies the Big Horn range, concerning the relations of which much too little is known.

PLAINS, PLATEAUS, OR ELEVATED TABLE-LANDS.

The lowest point reached during the trip was not far from 5,000 feet above sea-level. All that portion of country lying between the various mountain-ranges, and partaking of the nature of plains, must, therefore, be classed under the head of elevated plateaus or table-lands. Of the 19,300 square miles composing the southern half of the district under consideration, more than three-fourths belong to this class. The area of plateau-surface within the limits of the northern square will scarcely exceed one-third of the entire area of the square. Thus it will be seen that the total area of table-land is not more than six-tenths of that of the whole district; the remainder being occupied by mountains.

It will be unnecessary to describe in detail the several divisions of the plateau-surface, for they will require attention in various places in the following chapters, where their special features can be more fully discussed. Some general remarks in this place will, however, be useful to those who may be more particularly interested in the subject of this chapter, and it will also be found that some subjects will be explained by this means which would otherwise require much useless repetition.

The table-lands comprised within the limits of this district, excluding such as are of small extent or of minor importance, are four, viz: The Green River plateau, the Wind River plateau, the section to which I shall refer as the Shoshone plateau, and the Park plateau, occupying a portion of the Yellowstone Lake Basin.

The Green River plateau, as here understood, embraces the ellipsoid tract north of the Uintah Mountains, which, under the name of Green

River Basin, will be frequently referred to in this report, extending from the main divide of the Rocky Mountains westward to the Wahsatch range and bounded on the north, in its northwest corner, by the Wyoming Mountains. For the purposes of this review, it is convenient to take as its eastern boundary that portion of the continental divide between South Pass and the latitude of the Uintah Mountains. In reality, however, this is a semi-arbitrary line of division, and the separation of the Green River Basin from the Laramie plains east of the divide is rather geological than otherwise. Accepting this water-shed, then, as its limit, the Green River plateau occupies an area of not less than 16,500 square miles, its greater diameter extending from northwest to southeast. Its surface is now very much broken into low buttes and benches with intervening vales, so that the elevation varies greatly; but as this configuration has been accomplished mainly by the action of running water, we need now consider only the elevations of the various divides between the principal streams. A comparison of these shows that the plateau, as a whole, has an average elevation of about 7,000 feet above the level of the sea, and that there are several points upon the plain exceeding in altitude some portions of what is generally considered the Rocky Mountain divide.

The Wind River plateau, as the name indicates, lies upon both sides of the Wind River, between the Owl Creek and Wind River Mountain ranges, extending as a triangle from below Tó-gwo-te Pass as far as the Big Horn River, beyond which it passes out of the limits of this sketch. Its topography is even more irregular than that of the Green River plateau, and though not more than one-sixth of the latter in extent, it varies much more in extremes of elevation. It is safe to say, however, that the average altitude is considerably less than that of the Green River Basin. The whole tract lies upon the eastern slope of the Rocky Mountain chain.

The Shoshone plateau, extending east of the Sierra Shoshone and north of the Owl Creek Mountains, is irregular in outline as well as in its topographical features. In general shape it approaches the form of a narrow quadrangle, with its length in a north and south direction. Its extent beyond the limits of our survey cannot be great, at least toward the east. There are several prominent mountain-peaks over this district, but aside from these it is probable that the average elevation is less than in either of the two cases before mentioned.

Much of the area within the district reserved for the national park comes properly under the head of table-lands, and it will be convenient to describe the whole of such area as the park plateau. This will then include all the non-mountainous country comprising the Yellowstone Lake Basin, with the broad valleys of many of the large streams connected with or adjacent to it. A careful description would necessitate the division of this region into a number of districts, none of which would be of wide extent, but which differ so greatly in position and in altitude that they cannot well be correlated in any but the most general manner. The physical features of the Yellowstone Lake Basin may be mentioned here, leaving the minor areas to be treated elsewhere as occasion may require. To the south and southeast of the Yellowstone Lake the great continental divide, or watershed, is quite low, compared with the surrounding country, in many places, where it must be regarded as forming a part of the plateau which we are now discussing. Including this, the lake-basin has an average elevation exceeding by several hundred feet that of the Green River Basin. Its area is not great, and it differs from the three foregoing tracts in the amount of timber and other vegetation, which is doubtless a result of the more abundant supply of water. Its topography is more rounded and regular than is the case upon the "plains" before alluded to.

RIVER-SYSTEMS.

In this rapid review of those physical features of the water-courses of Western Wyoming, upon the cognizance of which a full understanding of many points in its geology depends, it will be advantageous to narrate the facts, as nearly as possible, in their geographical order, that they may be the more readily compared with the general topography as previously indicated. The whole of the district being highly elevated, we shall meet only with the headwaters portion of the great river-systems, but the number of the streams will be large.

In the extreme southwestern corner of the Green River plateau, the junction of the Wahsatch and Uintah ranges forms a double water-shed, which, according to the laws of the composition of forces, causes the resultant stream to flow off in a direction west of north. At this point rises Bear River, which pursues its tortuous course northward between the parallel ridges of the Wahsatch Mountains, occasionally cutting through them, until it reaches latitude 42° 42′ north, at a point about thirty-five miles west of its source, when it turns abruptly southward and works its way out of the range upon the western side to pour its contents into the northeastern prolongation of the Great Salt Lake, known as Bear River Bay. East of the main sources of Bear River the water-shed from the Wahsatch Mountains is unfelt, and the streams run northward, escaping to the plains nearly at right angles to the Uintahs. This is notably the case with Black's Fork, which rises well up in the Uintah Mountains, and, in a lesser degree with Muddy, Smith's, and Cottonwood Forks, which have their sources nearer the plains. East of these is Burns' Fork, and other tributaries of Henry's Fork start northward, but joining Henry's Fork, and finding no immediate escape from the mountains, they follow its cañon eastward, which receives all the mountain-streams along its course to the junction with Green River. All the streams originating east of the sources of Bear River, upon the northern slope of the Uintahs, flow directly or indirectly into Green River. The main sources of Green River, however, originate upon the southwestern slope of the Wind River Mountains, but it receives important tributaries from the east, and several, which come in from the west, rise in the outlying ridges of the Wahsatch Mountains, north of the Union Pacific Railroad. The main river flows across its basin in a general southeastern course. Green River and its tributaries may be said to drain the whole of the plateau, for the streams of other systems merely catch a portion of the surplus water from the corners, and, although in each case a source of an important river, they do not to a great extent determine the main course of their systems. They are, however, peculiar and important for some reasons, but it will be unnecessary to dwell upon them now, as they will be more fully treated in another chapter.

Passing to the Wind River plateau, we find that it is almost completely drained by the Wind River system, which receives nearly all the precipitation between the crests of the Wind River Range and the Owl Creek Mountains. All the tributaries of Wind River, with their affluents, which rise near the nucleus of the Wind River range, emerge from the mountains through narrow cañons in the outlying ridges, cut at right angles to the axis, or nearly so; hence it may happen that the separate sources of one of these rivers originate many miles distant from each other, and flow together from nearly opposite directions, until they meet to pass to the plains as one stream, by a narrow gateway, as it were. Near latitude 43° north, longitude 108° 30′ west, the Wind River turns abruptly northward, pursuing a very direct course to its junction with the Yellowstone River. Beyond this bend it is known as the Big Horn River. The tributaries of the Big Horn which rise in the Sierra Shoshone, viz, Owl Creek, Meeyera and Gooseberry Creeks, Grey Bull and Stinking Water Rivers, pursue a general easterly course, with a northward tendency, the latter increasing and continuing so that Clarke's Fork, the main Yellowstone below the lake, the three forks of the Missouri, &c., are found to flow almost due north for a considerable distance. The sources of the Stinking Water are so far to the west of the more southern tributaries of the Big Horn that it drains a very large proportion of the whole Sierra Shoshone, its branches extending far to the southward of the main head. Still farther to the south, however, this range is drained by some of the headwaters of the Snake and Upper Yellowstone Rivers, and it is in the vicinity of the point where these several streams originate that we have that peculiar water-shed which has been not inaptly termed the "Crown of the Continent."

The preceding review gives but the bare outlines of the physical geography of a most interesting region, and many subjects have been passed by without notice, while others have received but little attention; but enough has been written to make a detailed review of the geological structure of the region more comprehensible and valuable than it could be without a general knowledge of the facts related in this chapter.

There are many of the finer features or lineaments of the surface, particularly in mountainous countries, which are apt to be overlooked or lightly treated because of their apparent insignificance; and yet it not unfrequently happens that careful scrutiny will prove that they have been instrumental in shaping the outlines of a vast expanse of territory. It would be interesting to review these in a chapter by themselves, but it has been thought best to defer special mention until they can be more carefully noted in connection with the subject of dynamical geology.

CHAPTER III.

STRATIGRAPHY—METAMORPHIC AND PALEOZOIC.

Introduction—Pre-silurian era—Silurian system—Potsdam sandstone—Quebec group—Niagara limestone—Devonian system—Carboniferous system.

In collating and arranging the results obtained in this department of our subject, it has been deemed advisable to adhere strictly to the plan adopted in other portions of the report, and to present topics in chronological order rather than in the order of observation. This method will cause us to wander from point to point; but it will prevent much useless repetition, and give something like system to the work, which will render it more easy of reference; and it will also render more permanent whatever of value the report may possess.

As we proceed, it will become more and more evident that the chief value of the determinations in this department will depend almost wholly upon the relations which are found to exist between the rock-formations of this section and those of other parts of the country and of other countries; and particularly will it depend upon their relations to the formations of neighboring districts.

Fortunately for the writer, the explorations which have been made of late years in this region, under the direction of Hayden, King, and others, have rendered the tracing of the latter class of relationships much less difficult and more certain than could have been the case under less favorable circumstances. Although much yet remains to be done in various directions, it is but due to these men that grateful acknowledgment should be made of the value of the information which has been derived from the perusal of such of their reports as have been consulted in the preparation of this treatise.

To show at a glance the proper relations of the geological formations of Western Wyoming, the accompanying synoptical table of the deposits of the various epochs has been prepared, giving the formations representing them in different parts of the world as they are commonly named, in which one column is devoted to the deposits now to be described. This table is so arranged that each formation is placed in its proper relative position to all the others; at least, so far as it can be done with our present knowledge of the strata, and beyond this no explanation of its use is necessary.

METAMORPHIC ROCKS.

The question naturally arises, what is the earliest act of which any record has been discovered within the territory embraced by the reconnaissance? Such records must evidently be sought in the lowest rocks which are exposed over this area. It is now scarcely doubted that our globe has passed from a gaseous condition by successive stages to its present form.

Accepting this view, we are prepared to find that many of the rocks which were formed during earlier stages of the earth's history have been greatly altered since their deposition by the various kinds of action to which they have been subjected. Wherever, then, as in some parts of the district under consideration, sufficient force has been employed to rend apart or wear away the superincumbent strata, but without disturbing their relative positions, we may expect to meet with exposures of the underlying metamorphics. These exist in quantity throughout the region of the Rocky Mountains, but they are not well exposed in all of the ranges. In that portion of the Uintahs visited by the writer, they are mostly concealed by the overlying purely sedimentary rocks, as they are also in the Owl Creek range, though in the latter one or two fair exposures were noticed by Captain Jones from the summit of Phlox Mountain. In the Sierra Shoshone, it is almost impossible to determine whether the metamorphic series ever came to light; for, with few exceptions, the whole section is now covered by a formation which has been deposited since the elevation of its primary ridges. The Wind River Mountains furnish abundant opportunities for the study of these rocks, however, and they are extensively exposed in the Wahsatch range, according to the reports of Clarence King, Hayden, and other geologists. The central portions of the Rocky Mountain system, or, more properly, the crests of the Rocky Mountain chain, furnish the best exposures of these rocks.

In the Wind River Mountains, as in most other portions of the Rocky Mountains, the nucleal rocks occupy an irregularly-exposed belt along the axial line of the range. It is at least doubtful whether any true *igneous* rocks are here exposed; for the gradations between the compact and the gneissoid granites, and between the latter and the gneisses and schists, are so close as to point toward the aqueous or sedimentary origin of the whole series, At any rate, there can be little question that the exposures of purely igneous rocks, if any exist, are of very limited extent. It will, therefore, be convenient to consider the whole series as composed of metamorphic rocks, although the massive granites are so far changed from their original condition as to be *structurally* inseparable from igneous granites by any method of analysis known at present.

The rock most nearly approaching the igneous is a compact, fine-textured granite, containing an abundance of mica, apparently *muscovite*, with more or less of black *biotite* distributed through the mass; the latter, in places, becoming so abundant as to give character in color and mode of weathering to separate portions of the rock. These granites seem to be associated with gneisses and gneissoid granites, varying considerably in texture and composition; and these again pass somewhat gradually into the metamorphic schists, upon both sides of the anticlinal. Beds of quartz and reddish and flesh-colored feldspathic seams are met with, and quartz veins traverse the slaty metamorphics, charged with the gold which is mined in the neighborhood of South Pass. Some portion of these metamorphic rocks contains, besides the magnetic iron, (Fe_3O_4,) which is abundant, garnets, mostly quite small, but occasionally of fair size. These were accidentally discovered in large quantities in the bed and alluvial bottom of the Sweetwater River, at Camp 13. The feldspar seams in this section are mostly filled with nuggets, as it were, of muscovite. The quartz, in many instances, is quite pure and white; in other cases it is darker colored and frequently contaminated by the decomposition of pyrites.

Beginning below, or at the center of the mountain-nucleus, we have then the following succession of the metamorphic rocks:

1. Gray and reddish granites, with masses of black interspersed.
2. Gneissoid granites, passing through granitoid gneiss to—
3. Gneisses of varying composition and feldspathic seams.
4. Metamorphic slates and schists, with quartz veins containing gold and silver.
5. Pre-Potsdam metamorphics.

This will serve to show the general character of the series, though by no means intended as a complete section, which would require much more investigation than is possible in a mere reconnaissance. It is not improbable that a closer study would reveal many interesting facts in connection with the origin of many of these rocks. For instance, there is some ground for the belief that some apparently local actinolite schists and other allied forms may have originally been the trap-dikes of the early sedimentary strata now metamorphosed. Some rocks here classed among the metamorphics may be proved more recently trappean, but it is probable that such cases are very exceptional.

Other exposures of the metamorphic rocks occur along the route of the expedition. The granites appear at the surface over a considerable area in the valley of the East Fork of the Yellowstone, and in the valley of the Yellowstone River, between the mouths of East Fork and Hell-Roaring Creek. The structure of this section is deserving of close attention, for it cannot fail to add greatly to our knowledge of the dynamical history of a large portion of the Rocky Mountain system. North of latitude 43° 45′, and west of longitude 109°, every exposure of the deep-seated rocks is to be welcomed as an aid in the solution of difficult problems connected with the mountain-geology, because such exposures over a vast territory are rare indeed. There is here, perhaps, some evidence that a portion of the granites are igneous intrusions, or, rather, it should be said that there is less evidence to the contrary; and yet, upon the whole, I am strongly inclined to the opinion that they are no less metamorphic than those of the nucleus of the Wind River Mountains. Here we find the same general characteristics, with a similar succession of gneissic and schistose rocks, wherever full exposures can be reached. There is this difference, however, that not only the overlying metamorphic and sedimentary beds, but the granites themselves, bear traces of further change, owing, probably, to the subsequent ejections of molten volcanic products, which have flowed over them. This view is partially supported by the fact that in this region there occur granites composed of the same varieties and proportions of mineral ingredients as some from the Wind River Mountains, but differing in their arrangement, and consequently in texture. This feature is also noticeable in many of the micaceous sandstones, and in the schists, which have become more friable, and, like some of the granites, have the appearance of having been burned or baked. Quartz veins of various sizes occur in these rocks, and gold has been obtained from some of them in what appears to be a continuation northward of this system of ridges.

Between the Two-Ocean Pass and Tógwote Pass there are exposures of a metamorphic group, which undoubtedly represent the ridge of some mountain-range or its spurs, though it is a difficult matter at present to define its relations to the main chains; and the same remark will apply also to the section just discussed. Here, again, the same conclusions may be drawn from facts quite similar; and such trifling differences as are found to exist between these formations in the two localities may, I think, be readily reconciled by referring them wholly to differences in the amount of the pre-volcanic erosion. This will be rendered more apparent as we proceed, as it will be necessary to refer more than once to the evident changes in texture which have been produced in the rocks by the outflow of the later igneous material from volcanoes.

Age of the metamorphics.—Sufficient data for determining the exact age of this series have not been collected; nor is it by any means certain that this can ever be done. On account of the complete change which most of these beds have undergone since their deposition as sediments, it is possible that future research can do little more than to extend downward the series of rocks of known age by the transfer to it of one or two restricted groups from the upper beds of the metamorphic series. The structure of the Wind River Mountains is, however, so regular that it affords convincing proof of the *relative* age of such of these beds as are exposed in the nucleus of that range, at least in one direction. In other words, although it would be unwise to assert that they are identical with either the Saint John's, the Huronian, or the Laurentian system, as elsewhere known, without a wider knowledge of their relations, we may confidently affirm that no portion of the whole series was deposited later than the formation of the Potsdam sandstone in the Rocky Mountain region. There is a possibility that the comparison of facts from a large number of localities in the West may hereafter lead to some very interesting developments concerning these undetermined rocks. Certain it is that the succession of the strata throughout the Rocky Mountains is remarkably uniform, and a careful examination of the metamorphic rocks over an extended area would do much toward unraveling their history. Uniformity of lithological characters over broad districts is rare, even when the metamorphosed rocks were originally identical in composition, because slight differences in the amount or quality of action or resistance may cause great differences in the results.

There are some slight reasons for placing a portion of the oldest of these rocks in a group nearly equivalent to the Laurentian system of the East, but it must be confessed that none of them are based upon much better foundation than a certain similarity to that formation in lithological characteristics. Their position upon the stratigraphic chart is, therefore, entirely provisional.

SILURIAN SYSTEM.

As before remarked, no proof has been obtained of the existence in recognizable form of a set of beds which can be referred to the horizon of the Saint John's group of the Canadian geologists; although it is not impossible that some of the upper beds of the metamorphic series may be of that age. So far as can be determined from the hasty review which is rendered necessary in a simple reconnaissance, there are few, if any, indications of unconformability between any of these lower beds; but this is a question which can only be settled after careful examination over a wide space. In the valley of a small branch of Beaver Creek, at a point where the overlying sandstones have been cut through, the metamorphic slates appear in such a manner as to suggest unconformability between themselves and the Lower Silurian sandstone, but the exposure was so narrow and weather-worn that it was impossible to determine the physical relations of the two groups to each other. In most localities, the sub-sedimentary beds dip at a much greater angle than the overlying rocks, some of the former being very nearly vertical, while the adjacent strata are much less inclined. This, of itself, is not sufficient to prove the unconformability of deposition, however. Until we know more of the rocks comprising the metamorphic series, this subject of their "lie" is of minor importance, though it will be of consequence in determining their geological relations. One great difficulty in working out such problems in connection with a reconnaissance is that the route of the expedition must necessarily lie through the least rugged portions of the country, in which the geological structure is frequently obscured by drift and other later formations of mere local extent.

The Silurian system is represented by several important formations in the region of our survey, most of which probably underlie a vast extent of country west of the Mississippi, but which are concealed by the more recent deposits except in places where they have been brought to light by the upheaval of the mountains; and even here they have been again largely buried by the accumulations of later formations of non-sedimentary character. The lowest formation yet recognized is that of the widespread—

POTSDAM SANDSTONE.

Beds of a reddish sandstone, of varying thickness, with the structural and mineralogical characteristics of the Potsdam sandstone east of the Missouri River, were noticed some years since by Dr. Hayden at various places in the Rocky Mountains, from which a few characteristic fossils were obtained in some instances. The first discovery of these remains, announced by Meek and Hayden in March, 1858, in a paper read before the Philadelphia Academy of Sciences, was made in the region of the Black Hills, Wyoming, (then Nebraska.) Subsequently, Dr. Hayden reported other fossils, collected in the Big Horn range, near the head of Powder River, and in his report for 1870 he mentions the discovery of others in this formation near South Pass. On the geological map accompanying his report in connection with the expedition of Col. Wm. F. Raynolds, published in 1869, this formation is represented as an irregular band bounding the nuclei of all the prominent mountain-ranges. In the colored map which I have prepared to accompany this report, some modifications have been made in the distribution of these rocks, in certain sections, but they are not of sufficient importance to call for special notice. Unfortunately, though satisfied of the age of such rocks as I have referred to this formation by reason of their order of sequence, and their lithological features, I was unable to obtain any fossils from any of the exposures along our route.

In the Wind River Mountain district, there is a succession of beds of a loosely granular, almost friable sandstone, varying in color from red or brown below to white above; in texture, from a mere loose aggregation of the siliceous particles to fairly compact sandstones; in structure, from thinly-laminated or obliquely-laminated to thickly-bedded massive rock. The parallelism of these beds with much of the Potsdam sandstone of the East, even to minor peculiarities, is quite remarkable. The following statement concerning this formation is taken from the Wisconsin Report, (Hall and Whitney, vol. 1, 1862, page 141,) being a portion of Prof. J. D. Whitney's contribution to that work:

> The lower sandstone occupies the same position as the Potsdam sandstone of the New York geological survey, and is the exact equivalent of it. As developed in the Northwest, and especially in the State of Wisconsin, where it occupies a large extent of surface, it is made up of an almost chemically pure siliceous sand, in minute grains, hardly larger than a pin's head, which are held together by the minutest possible quantity of a calcareous or ferruginous cement. Frequently even this small quantity of cementing-material is wanting, so that the rock can be readily crumbled between the fingers, like a crystalline granular sugar. Where the ferruginous material, which is the peroxide of iron, becomes more abundant, so as to form 2 or 3 per cent. of the mass, the sandstone acquires a dark-brown color, and frequently affords a solid and durable building-stone.

This description will apply to the rocks of this group along the eastern slope of the Wind River Mountains. In the same relative position to the metamorphic rocks, there occurs, in the valley of Lava Creek, along the western base of the Sierra Shoshone, a thick formation, composed mainly of a compact red sandstone, almost a quartzite, portions of it being entirely made up of coarse grains of bright quartz, with quite small quartz pebbles distributed irregularly through the mass. Hayden also mentions a similar outcrop east of South Pass; and other exposures of apparently the same group as that on Lava Creek are referred to by Hayden and Bradley in the report of the Department of the Interior survey of 1872. The rock seen upon the right bank of Lava Creek is very hard, but it has the appearance before noticed of a partially-metamorphosed sediment, as if it had been modified by the outflow of the eruptive material, which has largely covered this section, and its imperfect jointing and consequent mode of weathering have probably been induced by the same cause.

Other geologists have described beds of this formation in other sections, and their remarks will often be found to apply almost equally as well to the exposures along our route. Emmons and the Canadian geologists, as well as Hall, Owen, and others, allude to peculiarities of this sandstone and its associated rocks, which are strikingly repeated in the Rocky Mountain region. Among these may be mentioned the peculiar lamination of some of the harder brown beds, which contain a considerable quantity of the ferric-oxide cement. A short distance beyond Miners' Delight, the present wagon-road from Camp Stambaugh to Camp Brown passes through a hollow, upon the edge of which the reddish-brown beds are exposed and weathered in such a manner as to present something of the appearance of crowded shelves in tiers. This is roughly represented in Fig. 1, which is a diagrammatic section in the direction of the *strike* of the rocks.

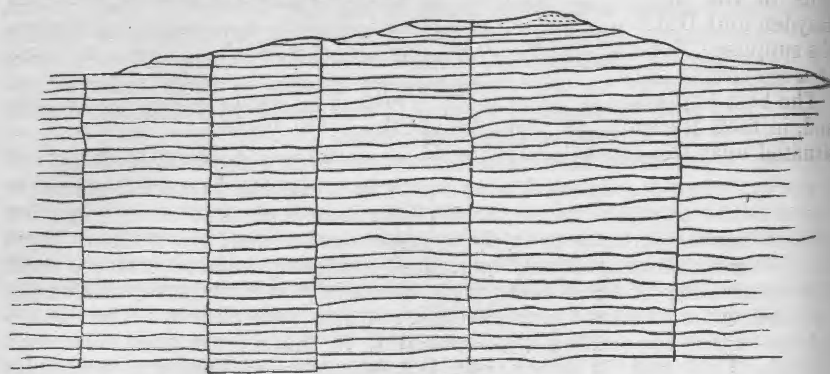

Fig. 1—Style of weathering of cliffs of Postdam sandstone, Wind River Mountains, near Miners' Delight. The lines all represent the uneroded portions; the spaces between representing the eroded portions. A portion of one stratum only is shown, hence there are no lines of bedding.

This form of weathering is doubtless owing partly to variations in the texture of the rock, which have produced the lamination or alternation of the fine and coarse materials, but, also, to other peculiarities induced by the erosive agencies.

The greatest thickness of the Potsdam sandstone over the area described is about 200 feet, in the region of the Wind River Mountains. All the beds bear evidence of deposition in shallow seas, or upon beaches or sand-flats.

QUEBEC GROUP.

Above the Potsdam sandstone in some sections, and probably in most places directly superimposed, occurs a set of beds which, for reasons that will presently be given, are referred to the horizon of the Canadian Upper Calciferous strata, known as the Quebec Group. As exposed along the eastern flank of the Wind River Mountains, these beds differ widely from the underlying sandstone-formation, and they furnish abundant proof of the deepening of the sea over the area in which they were deposited. Their distribution is not yet fully determined; but some interesting hints in this connection may, if they have been correctly interpreted, go to show that, though a wide-spread formation, it extends less regularly over the country than most of the beds below and above it. This conclusion cannot be considered final until the numerous missing links in the chain of the western geological history have been supplied by the more careful surveys of the future. The facts upon which it is based are briefly these: The geology of the eastern portions of the Rocky Mountain region has been *traced* over an extended space from north to south without the discovery of important exposures of this group of strata, which fact, to one acquainted with the differences of weathering between most sandstones and limestones, seems remarkable if such strata exist. Again, Hayden, after several good opportunities of observation, has expressed the opinion that no strata between those of Potsdam and Carboniferous age occur along the eastern slope of the Wind River range. This, as we shall see, is certainly an error, but it was based upon an examination of well-exposed sections at each end of the range, and there are some indications of the thinning-out of the Calciferous beds in the neighborhood of South Pass, which would partly justify his opinion. West of the Rocky Mountain divide, beds of the age of the Quebec group have been observed by both Hayden and Bradley; but, as is the case in several places on our trail, the supposed Potsdam is also to be seen immediately overlaid by rocks of more recent date.

The best exposure of these rocks which was reached during our trip, and, in fact, the only one from which the main facts were gathered, is situated near the central portion of the Wind River Mountains, a little

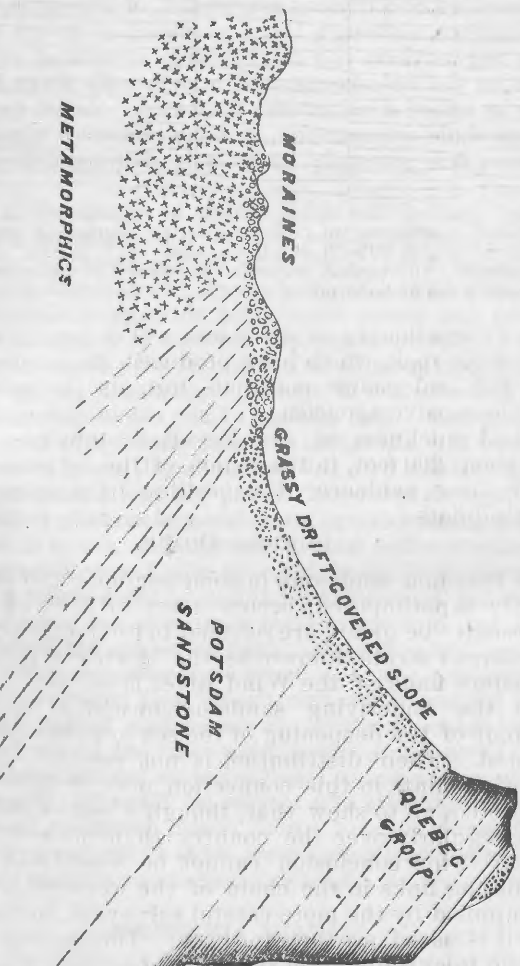

Fig. 2. Section showing an exposure of the Quebec group limestones, Wind River Mountains.

south of west from Camp Brown. The connection with the rocks below is entirely obscured by heavy drift-deposits, as will be seen from the accompanying section taken at a point where the overlying beds have been worn away, (see Fig. 2.) The thickness of the exposed Quebec limestones is about 200 feet, which will constitute two-thirds of its whole amount, if it be true, as supposed, that there is only a thickness of 200 feet of Potsdam sandstone between this formation and the metamorphic series, but which is not exposed in this section.

This supposition is not of much value, for there is no means of determining from this section the nature of the 300 feet which is covered by drift. One thing, however, is certain: there is nowhere in the Wind River range such a development of this formation as is reported by Bradley from several localities farther west, unless it be in a very restricted section.

The rock varies somewhat in composition and texture, but in general it may be described as a ferrous-magnesian, or dolomitic, limestone with an öolitic structure, although large portions of it are not öolitic. In some of the layers there is a considerable amount of siliceous material intermixed with the calcareous, and occasionally there is a bed which might better be called a calcareous sand-rock. Local bands or streaks of ferruginous shale are common, in some instances almost constituting separate layers, but generally irregularly dispersed through the limestones.

The greater part of the silica, which is contained in the dolomitic limestones, is exceedingly fine, but there is scattered through the rock a small amount of what appears to be the minute fragments of some silicates of black and orange-red colors. Occasional globular masses of *pyrites* ($Fe\ S_2$) are found distributed through the öolite, and "drusy" cavities lined with rhombohedral crystals of *calcite* are very common. Many of the fossils seem to be connected with the mineralization of the rock by the introduction of special ingredients in the place of their component minerals. The change of the calcic carbonate of the shells to *dolomite*, and the alteration of other shells into ferric oxide, or the filling of their cavities with the same mineral, are of common occurrence, and in some layers a species of *Theca* (?) is now almost invariably largely composed of a green mineral resembling *glauconite*, (silicate of iron.)

Organic contents.—The beds of the Quebec group in this region contain an abundance of fossil remains of a Lower Silurian cast, such as would require for their existence the conditions under which these beds were formed, viz, a comparatively clear sea, not necessarily of extreme depth, nor free from occasional slight turbidity, but highly charged with calcareous matter. As a rule, these fossils are quite badly broken, although the fragments are remarkably well preserved with few exceptions. In the öolite they are apt to be less broken than in the other limestones. From the few specimens collected I have been able to identify a trilobite of the genus *Dicellocephalus*, several specimens of *Orthis tritonia* (?) and a quantity of a species of *Theca* (?). Fragments of other fossils are present, some of which could, doubtless, be identified, with more careful study and comparison with better-preserved remains, but this has been impossible under existing circumstances.

NIAGARA LIMESTONE.

Until the time of the present reconnaissance, all of the rocks of Silurian age north of South Pass, and east of the main crest of the Rocky Mountains, were referred to the epoch of the Potsdam sandstone. Hayden discovered evidences of the existence of strata of Upper Silurian age near South Pass as early as 1860, but he did not meet with any indications of their presence elsewhere in the Wind River Mountains. The trip to Chimney Rock, made by the writer from Camp Brown, which is mentioned in Chapter I, proved very fortunate, as it resulted in the discovery of several important groups of strata not heretofore suspected in that region. The junction of the Quebec group with the underlying formation is still unsettled; but very near the section shown in Fig. 2 its connection with the formation above is rendered plain by an exposure, which shows the two groups in contact. Fig. 3 is a section illustrating the prominent facts as there exhibited.

Several other outcrops of a similar limestone along our trail have been referred provisionally to this formation on account of their relative position to other beds. Near the summit of the Owl Creek range, where

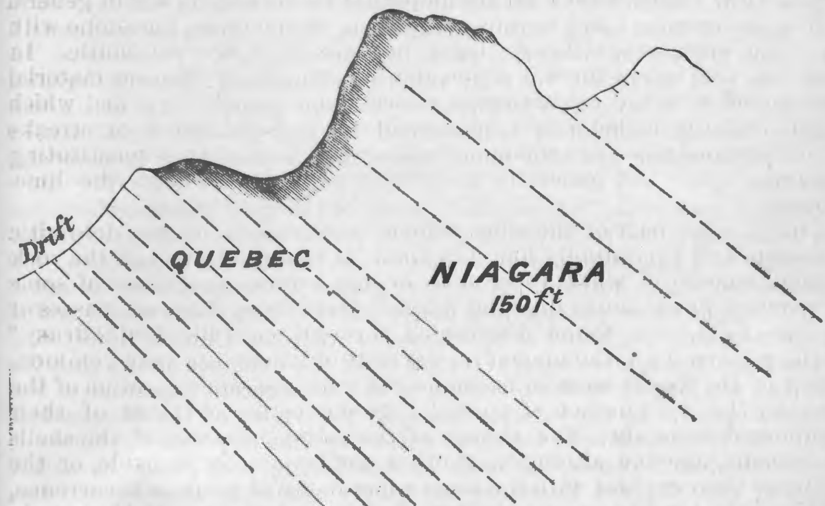

Fig. 3.—Section showing the connection of the Niagara and Quebec formations, Wind River Mountains.

we crossed it, there is an exposure of compact crystalline limestone, overlying a thinly-bedded shaly rock, which does not greatly resemble the limestones of the Quebec group lithologically, but which may be of the same age, though there are, perhaps, better grounds for considering it of later date. There are several exposures of thick limestone formations in the valley of the East Fork of the Yellowstone which have yielded no paleontological evidence of their true horizon; but, as they appear to lie not far above the metamorphic series, it seems more likely that they were deposited during the Niagara period than that they are of Carboniferous age, the rocks of which in this region they do not so closely resemble.

On Lava Creek, a locality before mentioned, the red sandstone which I have referred to the Potsdam epoch is directly overlaid by limestones, the upper portions of which are probably of Upper Silurian age, being very similar in many respects to the fossiliferous Niagara beds of the Wind River range. This opinion is strengthened by the discovery of a co-incident arrangement of strata in the neighborhood of the Téton range, forty miles west of this point, by Prof. Frank H. Bradley, geologist of the Snake River division of Doctor Hayden's expedition of 1872.

The lithological characters of this formation are very similar to those of some of the more eastern rocks of the same age. It is possible that a few beds of an arenaceous nature will eventually be included in the group, but, so far as its limits have been determined over the area which we are discussing, it is entirely made up of a compact cherty dolomite of a color varying from white to gray or light-drab. Some portions of it are inclined to weather brownish-yellow, but much of it only assumes a darker gray color upon exposure to atmospheric agencies. Large masses of the dolomite frequently weather into turreted or castellated forms, and sometimes huge blocks are left standing by themselves or tumbled down steep declivities into the ravines. Caverns of various sizes are also not scarce, affording fine shelter even for quite large animals.

Beautiful siliceous crystals are abundant in the rock in "drusy" cavities, many of them being highly ferruginous, while others are opalescent and some are concretionary, with an agate structure. Portions of the rock are also traversed by thin veins of chalcedony, interlacing and studded with minute and brilliant crystals of quartz. An occasional fossil is almost completely transformed by this process. Nodules or flakes of *hornstone* are also found sometimes approaching in color the *carnelian.*

Organic contents.—Unfortunately, some of the most characteristic fossils belonging to the rocks of the Niagara period are not sufficiently characteristic of a single formation to enable one to refer the beds containing them to their exact horizon. A cursory glance at the specimens collected in 1873 might cause considerable doubt whether these beds would not be as appropriately regarded as synchronous with the Clinton limestones of the East, but a more careful review of all the evidence shows that the affinities are largely in the direction of the more recent limestone of the Niagara epoch. In the interior basin, in the valley of the Mississippi, where the limestone-beds are more extensive than at points farther east, the lithological features, the mode of weathering, and other characteristics of the Niagara limestone strikingly resemble the peculiarities which have just been described. But the comparison does not end here, for the character of the fossils also points to the more recent date of this formation in the Rocky Mountain region.

Perhaps the most common organic remains are those of the well-known *Halysites catenulatus*, Linn., or "chain-coral," which can be obtained in quite large masses. Other corals, of the genera *Cyathophyllum* and *Zaphrentis*, are not rare in the lower beds, and a brachiopod, poorly preserved, resembling a cast of the interior of *Pentamerus* (*galeatus ?*) was collected, besides one specimen of an *Orthoceras.*

The fossils, with the exception of the brachiopods, are usually silicified and very well preserved; but they are difficult to collect on account of the extreme hardness of the rock.

ABSENCE OF THE DEVONIAN SYSTEM.

Overlying the Niagara dolomite there is a series of beds which are mostly arenaceous, but which promise to prove of much geologic interest when they shall have received their due share of attention at the hands of those who will not be obliged to merely "skim" the country. In a paper published in the *American Journal of Science*, (vol. vi, December, 1873,) I have too hastily referred certain of these arenaceous strata in the Wind River Mountains to the Oriskany Period of the Devonian age. Prof. James Hall, of Albany, N. Y., who has since kindly examined two specimens obtained from this locality, writes that one proves to be identical with *Spiriferina pulchra*, Meek, a form originally described from Nevada; while, concerning the other, he remarks;

"Strange as it may appear, I am unable to refer it to any other than *Spirifer cameratus*, from the ordinary forms of which it differs considerably. The characters of the specimen are certainly obscure, and the determination may admit of doubt; but * * * I should give it the relations I have indicated, and, if not *Sp. cameratus*, it is to me unknown at the present time." It is probable, therefore, that the Devonian system is not represented by any considerable formation in this section of the West, although there is a wide field for research here; and, if this view be correct, the development of the Upper Carboniferous is quite remarkable.

CARBONIFEROUS SYSTEM.

Above the Niagara limestone, there is a well-developed and widely-distributed formation, which was early referred to the Carboniferous system. Beds of this age are quite generally exposed all along the flanks of the principal ranges of the Rocky Mountain chain, and occasional exposures of beds, which are usually considered synchronous with them, occur in many places west of the main crest, where it is often difficult to determine their relations to the adjacent rocks. Recent discoveries have made it doubtful whether such reference has not too often been based upon the previous supposition that there were no beds in this region between the Potsdam sandstone and the Carboniferous rocks, so that it is possible that some outcrops of an earlier date have been inadvertently reported as of Carboniferous age.

SUBCARBONIFEROUS ??? LIMESTONE.

The limestones of the Carboniferous age, flanking the ranges of the Rocky Mountain system, with one or two exceptions, have been generally regarded as of the horizon of some portion of the Carboniferous period, (the terms *age* and *period* being technically employed here.) In another place,* the writer has expressed the opinion that this formation, as exposed in a portion of the Wind River Mountains, north of South Pass, is of Subcarboniferous age. That statement was made from a review of the notes taken in the field, without the opportunity of further examination of the specimens collected, and it is now so far modified as to be less confidently expressed, for reasons which will presently appear.

The rock in question (the arenaceous beds before mentioned being excluded from the present review) is a bluish-gray dolomitic limestone, quite compact and thickly bedded, with numerous crystalline facets and geodes of *calc-spar*, besides occasional minute crystals of some foreign minerals. Some beds which seem to belong to this age are exposed in the cañon of the North Fork of the Stinkingwater River, showing, in an interesting manner, the effects produced by the molten volcanic outflows, portions of which have passed in between the upturned layers, transforming the sedimentary rocks into forms with peculiar characters.

Organic contents.—Much of this limestone is quite fossiliferous, but there is so little difference in the mineral composition of the rock and its contained remains that it is often difficult to procure specimens which can be readily identified, and this difficulty is not lessened by the irregular manner in which the fossils are crowded together. Several recorded specimens, containing remains from a favorable locality, have been

*In a paper "On the Geology of Western Wyoming," by Theo. B. Comstock, published in the American Journal of Science and Arts, vol. vi, December, 1873.

lost, so that the material on hand for final determination is far from complete. Among the missing were a crinoid of the genus *Poteriocrinus ?* and two or three specimens of *Lithostrotion*, as recorded in the field-notes. If my determinations of the remaining forms are correct, this limestone also contains *Spirifer biplicatus*, and a *chonetes* closely allied to *C. variolata.*

By some this might be deemed sufficient ground for the omission of the interrogation-marks after the word Subcarboniferous at the head of this section, but in view of the novelty of such a designation, as well as the doubt, which must be confessed, as to the validity of all the determinations, it is best that it should stand as it is.

There is also another reason for doubt. It is known that limestones of the age of the Coal-Measures occupy the position of this formation over a very large area in the mountainous region of the West, and it is difficult to imagine such a state of things as would have been necessary for the deposition of a restricted Subcarboniferous group immediately followed by a period in which the absence of any deposition was geographically identical, without some marked evidence being visible in the arrangement of the strata. So far as known at present, there is no ground for the belief that there is any break of this kind structurally, unless it be that an observed change in the character of some of the Carboniferous beds in the Big Horn range, reported by Hayden, may indicate a difference in horizon. As the subject now stands, it would be unwise to press too strongly an opinion of the Subcarboniferous age of this group; and it will be best to regard the whole series as Upper Carboniferous, according to previous authorities, until the matter can receive more thorough investigation.

CARBONIFEROUS LIMESTONE.

Near the head of Wind River, overlying conformably the Subcarboniferous ? limestone, there is a thick formation of arenaceous and calcareous beds underneath the brick-red sandstones usually regarded as Triassic. Toward the base of the group, from a non-homogeneous dark-gray limestone, I obtained a portion of a tooth of *Psammodus*, and shells undetermined, which have led me to place it in the Carboniferous group or Coal-Measures. The rock resembles limestones of this horizon in Illinois and Indiana. This was met upon the return trip, and no opportunity afterward occurred for reaching another exposure. Its reference must, therefore, be regarded as provisional. If the limestone referred doubtfully to the Subcarboniferous be really the equivalent of Hayden's Carboniferous east of our district, this formation would seem to occupy the position of his Permian. The determination of the *Carboniferous* eastward rests on such good authority as Prof. F. B. Meek, and cannot be questioned without better evidence than I can offer. These difficulties can readily be settled by those who may hereafter have occasion to work in this region, by the collection of more material from each formation.

The sandstones and arenaceous limestones before mentioned, from which the supposed *Spirifer cameratus* was obtained, *underlie* beds which are apparently continuous with those which have been referred very doubtfully to the Subcarboniferous period, which fact adds another element of uncertainty to the determination. Accepting, therefore, the opinion of previous explorers, the thickness of the Carboniferous limestones, the equivalent of the Upper Coal-Measures of the Eastern United States, is not less than 2,000 feet (probably much more) in the

Wind River Mountains. The entire absence of coal and the prevalence of calcareous strata, as well as the widespread distribution of the formation, all point to the existence of an extensive sea of considerable depth during the period of their formation; and no evidence has thus far been collected of a shore-line in any part of this region during the era in question. The upper limestones are massive and very compact, forming prominent ridges, with even, well-worn slopes, while the underlying strata are more thinly bedded, being usually less calcareous.

Organic contents.—Besides those already mentioned, no fossils have been identified. But few opportunities occurred of obtaining a good supply, and the general toughness of the rocks renders it difficult to procure them in excellent condition. As a rule, they are much crowded, and poorly preserved also.

OBSERVATIONS ON THE PALEOZOIC STRATA.

There is yet too much to be learned concerning the geology of our district to make any but the most broad generalizations useful, but the results of this expedition, in a geological way at least, will prove barren indeed if they do not furnish future explorers with a few hints of some of the unsolved problems yet remaining, that they may know where to seek for new facts for their elucidation.

It has been already remarked that the Potsdam sandstone and the Carboniferous limestone are widespread formations in the region of the Rocky Mountains, and that over the greater portion of the area east of the main divide these two formations have heretofore been reported in contact. Knowing now that several other formations intervene in certain sections, it is natural to seek a reason for their apparently local distribution. Two or three explanations are suggested by the facts as far as they have been gathered. First, it will be noticed that few competent geologists have traversed this region, even in such a manner as to collect all the data necessary for the mere tracing of the prominent outcrops of the successive formations, and none have been able to obtain more than a bare outline of the geological structure of any portion. It seldom happens in a reconnaissance—and territorial surveys are usually nothing more—that one can obtain information to any extent at a distance from the trail of the expedition; and the route pursued must of necessity be mostly away from the rugged country, making it impossible to reach the most instructive sections in all cases. Thus it may have happened that many exposures of the Quebec and Niagara strata have been entirely overlooked. This supposition, however, to one who has engaged in western field-work, will have little weight, and the wiser conclusion will be that such strata do not exist where they have not been reported, except it may be in small patches. But there is another question which is not so easily decided. Did these formations once spread over this whole area, or were they deposited in patches as we suppose them to exist at present? An examination of the limestones and their fossils shows that they were deposited in saline waters of considerable depth and extent, as a sea or ocean. Moreover, during the Quebec epoch the shore need not have been very far distant from the present position of the Wind River Mountains. A comparison of the statements concerning that group in this chapter with the reports of Hayden and Bradley shows that this formation rapidly *thickens* westward, while there is no doubt that it *thins out* southward and eastward, so that it is very thin, if not entirely absent, in the vicinity of Miner's Delight. The same features are noticeable with the

Niagara dolomite, which, as before stated, probably extends farther eastward than the Quebec group.

If this idea be correct—and it seems well supported—there was an ancient shore-line during the deposition of the Quebec and Niagara groups, of uncertain trend, but a portion of which lay near the longitude of South Pass. This opens a new field for research in this region, one which will doubtless add much to the great mass of facts which are now helping on the settlement of the theories of mountain elevation; and it also suggests the possibility that the history of the far-past in the West is not as simple as many have believed.

CHAPTER IV.

STRATIGRAPHY, CONTINUED—MESOZOIC AND TERTIARY.

Triassic system—Jurassic—Cretaceous and Tertiary systems—Age of the lignite formation.

We have seen that over much of the region north and west of South Pass the earlier Paleozoic rocks were deposited in a sea at first shallow, but somewhat gradually deepening until toward the close of the epoch of the Niagara dolomite, when comparatively shallow seas were the rule. During a considerable portion of the Devonian and Carboniferous ages, it is probable that dry land existed over at least a portion of this region; and east of the Big Horn River, it would seem that, during much of the era between the deposition of the Potsdam sandstone and the Carboniferous beds, the land was not covered by the sea. However this may have been, there is abundant proof that the barrier was overflowed at least as early as the close of the Carboniferous age, since which time the geological history of the whole area has been essentially the same, generally speaking.

TRIASSIC SYSTEM.

Directly overlying the limestones of Carboniferous age a thick series of brick-red sandstones forms one of the most peculiar and conspicuous features of Rocky Mountain geology. In most places where these beds are well exposed they stand out prominently by themselves, their separation from the underlying hard limestones being extremely distinct, on account of the great difference in the texture of the formations and the consequent greater erosion of the so-called Triassic strata. The brick-red sandstones are generally considered Triassic, though full proof of their age cannot be said to have been obtained. Notwithstanding the fact that these beds are among the best exposed of any of the western formations, less is probably known of their true relations than of those of all the others, except the metamorphic series.

Frequent exposures of the red sandstones occur over our district, but often the forces which have operated to bring them to light have also aided in again obscuring their structure. The most simple outcrop, not complicated by folds or subsequent deposits, is to be seen in the cañon of Deep Creek, at the base of the Wind River Mountains. Figure 4 is intended to represent a section across this cañon at a right angle to the axis of the range, but it also includes a portion of the exposures upon each side as they are seen along the banks of the Little Popo-Agie River.

Some outcrops in deeply-eroded vales in the Owl Creek range are quite similar, but many of the finest exposures are in eroded folds, several of which occur in the Wind River Valley, between the two mountain-ranges. In these, the dip of the red beds is often very great. Ripple-marks, and other evidences of deposition in shallow water, abound in most of the strata.

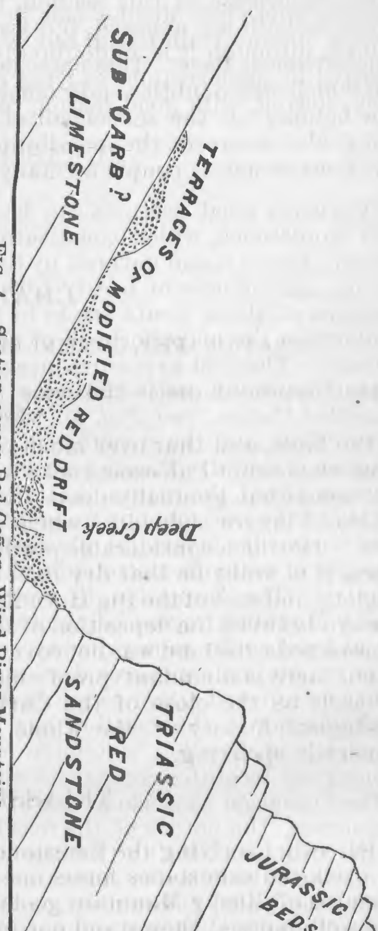

FIG. 4.—Section across Red Cañon, Wind River Mountains.

The rock appears to vary but little over broad areas, though occasional beds of a different nature from that of the red sandstones have been observed. Besides the ferric oxide, to which the color is mainly due, much of the rock contains a considerable quantity of iron in spots scattered through the interior like fossils, but showing no structural markings. Many of the layers are fairly compact, and being traversed by a double system of regular joints, they break into blocks of a form and size suitable for building-purposes. Large quantities of bedded gypsum occur, apparently interstratified between the layers of the sandstone in many places. A short distance below Camp Brown on the Little Wind River, this is quite abundant, and it bids fair to become of much economic importance in the future. At the head of Lake Fork, in the cañon, there are also extensive outcrops of this mineral, which are very accessible. The greater part is probably in the form of saccharoidal or compact alabaster, but some portions closely resemble in properties the finer varieties of anhydrite, and it is not impossible that other portions, in places where the rocks have been folded, may prove valuable as a partial substitute for marble, as is the case with the vulpanite of Northern Italy. In most cases, however, the anhydrite has been broken into quite small blocks by the heat accompanying the uplift. Some extensive beds of selenite were also observed. Beds of limonite, some of which appeared to be of the argillaceous variety known as yellow ocher, were noticed in the outlying ridges south of the Owl-Creek range, a portion of which may be of Triassic age.

Above the brick-red beds two or three hundred feet of lighter-colored sandstones, containing less ferric oxide, lie beneath arenaceous limestone-beds, affording a transitional series between the so-called Triassic beds and the succeeding strata of undoubted Jurassic age.

Organic contents.—The rocks of this age in Northwestern Wyoming are as barren in the evidences of life as the Potsdam sandstone, and it is seldom that one is so fortunate as to collect any fossils from them, except when making a specialty of their study. None were obtained by the writer in 1873, hence no new facts were elicited concerning the age of this formation. There can be no doubt that it is older than the Fossiliferous-jurassic of this section, for it is invariably found beneath it wherever both are exposed, but its limits cannot at present be clearly defined, although it is undoubtedly Post-Carboniferous, for it has been reported in some sections as lying unconformably upon beds which have been referred, with good reason, to the Permian period.

JURASSIC SYSTEM.

Wherever good sections can be reached, the brick-red and buff-colored sandstones, which constitute the provisional Triassic system, are almost always found covered by the Jurassic limestones, a group which attains a thickness of nearly 1,000 feet in some localities. Many fine outcrops of these strata are to be seen in the Wind-River country, particularly in the neighborhood of the mountains, upon both sides of the plateau. The first exposures upon the northeastern slope of the Wind River Mountains are in the main as simple as on the Little Popo-Agie near Red Cañon, (see Fig. 4), where there are no complications in the way of folds, and the structure is not obscured by accumulations of drift or other material. Passing across the plateau several prominent folds have so tilted the strata that the Jurassic beds outcrop at different angles to the horizon, but frequently dipping almost vertically, in which case the harder layers jut above the softer intermediate beds, often to a height of many feet, stretching like so many irregular walls across the country. The formation is very widespread, its distribution in the Rocky Mountain region being nearly identical with the supposed Triassic, at least so far as our district is concerned. West of the main divide, on our route, no exposures were observed of rocks, which can with certainty be referred either to the Jurassic or the Triassic, but the existence of the former in that section has been proved by the explorations of Hayden and Bradley, who have obtained characteristic fossils of this group from localities comparatively near.

The formation as a whole might be characterized as one of impure limestones, the nature of the fossils, as well as the composition of most of the strata, indicating that the beds were deposited during an epoch of marine subsidence in comparatively shallow water. The beds composing the walls, before mentioned as occurring in certain sections, are generally quite hard and compact, but they are not remarkably homogeneous. The proportion of *silica* is always large, seldom extremely fine, but often quite coarse. In the more calcareous strata, containing fossils, *alumina* seems to be present only in small quantity when compared with the amount which is contained in less arenaceous rocks of earlier date. The fossiliferous limestones are dolomitic and often somewhat ferruginous. Crystals of *calcite* and *dolomite* are very commonly distributed through all the rocks, and much of the magnesian limestone is traversed by numerous very thin joints, filled with veins of *calcite*.

The prevailing color of the rocks is a dull leaden or ashy gray, weathering from darker gray to brown and dark brown. Occasional beds of quite pure yellowish-white limestone are seen, also yellow and brown arenaceous limestones. It is probable, also, that this formation in the neighborhood of the Owl-Creek range, upon its southern flank, includes some valuable iron-ore beds; but, as before remarked, they cannot be properly placed until the boundary between the Triassic and the Jurassic shall be more definitely fixed, and this cannot well be accomplished until more complete paleontological evidence has been collected from the lower series of arenaceous beds.

Organic contents.—Characteristic Jurassic fossils have been more than once collected from the region of the Rocky Mountains, and the announcement of those collected from the Wind River Valley by Dr. Hayden, while acting as the geologist of Captain Raynolds' expedition, was made as early as 1861. These remains present strong resemblances to many of the species which characterize the lower strata of the Jurassic system in Europe. A good supply was collected from the various exposures seen upon the trip of 1873, but inopportune circumstances have made it absolutely impossible to work them up with any degree of care, so that it must be acknowledged that there are a number of forms which have not been made out which it is believed will add some new members to the list of the characteristic organic remains of the American Jurassic. Enough has, however, been learned to determine the age of the containing beds, without a doubt, for their separation from the overlying group is very distinct, stratigraphically and paleontologically, as has been well remarked by Meek and Hayden.

Among the forms which are most readily recognizable, there is a species of *Gryphaea*, bearing some resemblance to the European Liassic *G. Arcuata*, Lam., but perhaps nearer *G. Calceola*, Quenstedt, (which I have not seen represented.) Fairly preserved specimens of *Monotis curta* (?) were obtained, besides a few of a species of *Rhynchonella*, specimens of the genera *Lingula* (*brevirostra* ?) *Modiola*, etc., and two specimens of *Belemnites*, near *B. densus*.

CRETACEOUS AND TERTIARY SYSTEMS.

Perhaps there is no question of greater interest connected with western geology, nor one which has attracted more attention of late years, than the determination of the upper limit of the Cretaceous deposits. The beds of this age are usually found to be so distinct from the Jurassic strata that it is seldom very difficult to define the boundary between these two formations, but there is an important group lying between the known Cretaceous and the undoubted Tertiary rocks, the age of which has not yet been conclusively settled. Some geologists, with much apparent reason, are disposed to regard the majority of these intermediate beds as Tertiary, while perhaps a larger number are of the opinion that the weight of evidence thus far obtained places them more properly within the limits of the Cretaceous system, and not a few, taking a middle view, favor the idea that they are largely transitional in character. The opportunities afforded for the collection of facts bearing directly upon this question were not many during our trip, as the route followed was not such as to offer good outcrops of the beds under discussion. No opportunity has since occurred for the elaboration of any of the material which might throw light upon the subject, and it will therefore be necessary in this place to pass it by with much less notice than it deserves. Leaving the matter for some further consideration at the close of the chapter we will now proceed to a review of the Cretaceous beds, as far as full evidence exists of their true age.

CRETACEOUS STRATA.

As a rule, the Jurassic beds are conformably overlaid by the members of the Cretaceous series, and the distribution of both formations is, in the main, identical east of the Wahsatch chain, although the Cretaceous system is made up of several more local groups. In the Wind River Valley the beds overlying the Jurassic strata are exposed in much the same manner, but there are fewer good outcrops, owing to the more extensive covering of the Cretaceous by the Tertiary rocks, in the neighborhood of the Wind River Mountains, and to the greater erosion of the Cretaceous beds when they occur in the uncovered folds. North of the Owl Creek range it is probable that these strata are favorably exposed for study over a wide district, but in many places they have been so much folded and eroded that their stratigraphical relations to the adjacent formations cannot be satisfactorily worked out in a single trip across the country. Sufficient evidence was obtained, however, to show that there is no want of conformity between the Jurassic and the Cretaceous within a considerable distance of our trail. About half-way between Pacific Creek and Lava Creek the trail crosses the deep gorge of a small stream, where some of the Cretaceous beds are to be seen dipping southwest 57°, and in the cañon of Buffalo Fork, just below Camp 56, similar beds, with additional members, are found dipping in the opposite direction 89°. Between these points no Cretaceous exposures were noticed, but, judging from the dips of the lower sedimentary strata, which were observed on Lava Creek between Camps 55 and 56, there must be one or more folds intervening.

The lithological characters of the included members are almost as variable as possible, with intimate mixtures of arenaceous, argillaceous, and calcareous ingredients, in different proportions. There are very few beds of limestone, and such are always very thin, but there are some shaly layers, and even occasional beds of clay, though the formation, as a whole, would best be designated as an argillo-arenaceous group. Some of the shales, as well as many of the sandstones, are highly ferruginous, while other layers are quite free from the presence of iron. Much of the ferric oxide can be traced directly to the plant-remains which abound in parts of the group, but a large portion is undoubtedly due to the decomposition of pyrites. Passing up through a thick series of strata, with the arenaceous material somewhat gradually increasing in proportion, several beds of lignite, or impure bituminous coal, are reached, which are well exposed for working in many places. More will be said of their economic value in another chapter, but it may be mentioned here that the beds are of considerable thickness, and that they contain much sulphur and ferric oxide, besides a notable quantity of gypsum, all resulting very largely from the decomposition of iron pyrites, which is abundant in the coal. Beautiful grains or drops of amber, usually not larger than a pea, are also rather common, and, rarely, a short piece of the stem of a plant, several inches in circumference, will be found so completely carbonized as to approach somewhat closely to anthracite. These lignite beds are usually separated by several feet of soft sandstone, frequently of a yellow color, and they are directly underlaid by a peculiar hardened clay, or soft, clayey shale, to which it is, as it were, cemented, the lignite becoming browner below, and running into the shale almost gradually.

Three of these coaly layers are exposed upon the northeastern flank of the Wind River Mountains, and what appear to be the same beds can be traced by numerous exposures across the country to the southern flank of the Owl Creek range, while, perhaps, similar outcrops over the area beyond, as far as the Stinking Water Cañon, North Fork, may not be improperly referred to the same horizon. There is more or less of variation in character and quality over this district.

These lower lignitiferous seams are generally included in the Cretaceous groups by those who have studied them, whatever may be their views concerning the age of the doubtful beds which occur higher in the series; and this conclusion seems supported by the paleontological evidence. In the Wind River region, as well as over the district traversed in 1873, north of the Owl Creek range and east of the Sierra Shoshone, the great bulk of the Cretaceous formation appears to lie below the lignite beds, and it is supposable that the whole group, as there exposed, was deposited before the changes took place which resulted in the deposition of the strata of doubtful age.

Organic contents.—It will be impossible now to give even the genera of the distinctively Cretaceous fossils, but this lack will be less felt from the fact that Hayden long ago gathered evidence that the Wind River Valley deposits underlying the horizontal Tertiary strata are mainly of Cretaceous age. The remains of marine life are of Cretaceous types, and there is, as yet, little or no evidence of a great thickness of uncertain beds of brackish or fresh water origin. Still it must be confessed that this formation has been, at the best, but hastily examined, and changes in the character of the beds above appear to begin toward the head of Wind River, and to increase in importance westward. Near Gray Bull River some interesting plant-remains, mostly leaves of angiosperms, were obtained, and some very fine leaves in shale were obtained near the top of the section exposed upon the left bank of the cañon of North Fork of Owl Creek. The latter resemble so closely in character and position, and in the nature of the rock, some very good specimens collected in a bluff upon the left bank of Wind River, a short distance below Camp 58, that there can be little doubt that they are from the same horizon. In both cases I am disposed to regard them as Cretaceous, though the dip of the beds is much less than that of many of the underlying rocks. At any rate, the overlying Tertiary beds in the Wind River Valley are horizontal, or nearly so, and unconformable to these beds, while it is impossible to draw a similar line of unconformability between any two of the lower formations, although some of the beds dip much more than the plant-layers. The same relative arrangement of the principal formations was also observed north of the Owl Creek Mountains, where there are variations in degree but not in the order of superposition.

The outcrop before mentioned, which is exposed in the cañon of Buffalo Fork, affords a fine section of arenaceous and carbonaceous strata, with abundant remains of plant and animal life, which seem to bear affinities to Cretaceous types. These will be more fully discussed in connection with the remarks upon the age of the doubtful lignite group.

TERTIARY DEPOSITS.

Passing over the debatable ground for the present, we find that sufficient land had appeared above the sea at the close of the era of the lignite deposition for the existence of extensive fresh-water lakes over much of the Rocky Mountain region. Some of the lake-basins far exceeded in area the largest of modern depressions containing fresh water, and in them were deposited immense quantities of the detritus brought in by the streams from the surrounding country. This process in some places continued until the sedimentary material had accumulated in the bottom of the lakes to a thickness of hundreds, and even thousands, of feet. The important chapters of the earth's history, in which the records of these events are minutely recorded and profusely illustrated, might have remained a sealed volume had not the later history of our globe required for its records the waste of what had been built up during the long Tertiary period. As it is, the draining of most of the old Tertiary lake-basins has been accompanied with erosion upon a scale so vast that it is often possible to obtain a nearly complete section of these enormous accumulations by merely passing across the basin in which they were deposited. A very few years since it was scarcely believed that the Tertiary deposits of our country were capable of yielding so rich a harvest as had been reaped from beds of this age in Europe, but it is now ascertained that they are not surpassed in interest or prospective importance by any known group of strata in the world. To one at all familiar with the general geology of the United States it is only necessary to mention the names of Newberry, Lesquereux, Marsh, Leidy, Cope, and Meek to call to mind the rich results already obtained by the careful study of specimens collected from this horizon in the West. One of the most remarkable sections, the favorite field of several of the most experienced collectors, is situated in a portion of the territory embraced by our reconnaissance, and it therefore claims a share of our attention.

The greater portion of the Green River Basin, (as defined in Chapter II,) is now occupied by fresh-water deposits of the Tertiary period. A section of these beds from top to bottom will, however, include a considerable thickness of the lignite formation. Excluding this from the review, we shall have to consider here only that part of the series which is exposed in the vicinity of the road traveled between the Uintah Mountains and South Pass.

EOCENE STRATA.

In view of the discrepancies found to exist between supposed synchronous strata in different parts of the world, the plan of employing local names to designate the various epochs and periods represented in the United States, has wisely been adopted by field geologists. Strangely enough, however, the evident advantages arising from this method when applied to the Paleozoic rocks have been overlooked in the classification of the later formations, so that our Tertiary nomenclature is now encumbered with terms which are even less appropriate than would be the names, "Lingula Flags," "Llandeilo Flags," and "Wenlock Beds," applied to American Silurian strata of the same adjudged horizons. The terms *Eocene*, *Miocene*, and *Pliocene*, are particularly objectionable in American geology, and it must be distinctly understood that they have no more literal significance at present in the West than does the term *Triassic* when applied to the formation succeeding the Permian.

There has been some doubt concerning the proper disposition of the beds overlying the lignite or coal group, which were referred to the Middle Tertiary (Miocene) by Hayden in his report for the year 1870. This reference was largely based upon the supposd Eocene age of the coal-formation of the Green River Basin. Dr. Newberry, after examining a very few of the fossil plants from near Green River station, remarked that they hinted of an earlier period than the Lower Miocene. Professor Cope pronounced the age of the Green River fishes to be more likely Eocene, and during the same year (1870) that Hayden crossed the basin, Prof. O. C. Marsh determined to his own satisfaction that some still higher beds are Eocene, since which time he has two or three times visited the locality (Grizzly Buttes) and obtained more evidence. Professors Leidy and Cope, who have also collected and described numerous vertebrate remains from this section, regard them as Eocene. The weight of authority thus seems to favor their reference to the Lower Tertiary. My own conclusions, somewhat tardily adopted, were partially formed in the field, but have not heretofore been advocated for want of decisive proof. I can now express more confidently the opinion that these beds are of Eocene or Lower Tertiary age, although the paleontological evidence which I have collected is less satisfactory on account of the fresh-water type of the invertebrate remains, than would be the case were there more vertebrate forms. The collections have not yet been carefully examined, and it is therefore impossible to speak of them in detail.

Hayden has provisionally divided the beds comprising this remarkable formation into two groups, which may be conveniently recognized in the present state of our knowledge concerning them, though no definite line of separation can be drawn between them.

GREEN RIVER GROUP.—(Lower? Eocene.)

This name is at present used to designate that portion of the fresh-water Tertiary strata which lies directly above the coal group, and which is the present surface formation over a large portion of the Green River Basin north of Fort Bridger. If it be true that the coal-beds are of Eocene age, this group holds a position which will entitle it to be ranked as Middle Eocene, but if, as many believe, the former group be really Cretaceous, these beds may be considered Lower Eocene, there being in this case no Middle Eocene, unless it shall be found that the whole series is made up of three well-marked groups, which does not now seem probable, to say the least.

The upper limit of the Green River group is not readily definable at present, the transition between the beds of this and the overlying group being rather gradual, but the general character of the two formations, both lithologically and paleontologically, differs greatly. The Green River beds are mainly composed of a series of shales, marls, and harder calcareous strata, the latter, especially, containing quantities of the remains of fresh-water forms of life, with laminated layers literally filled with the remains of land-plants of the Phænogamous series. The famous "petrified-fish beds," so well exposed near Green River station, Union Pacific Railroad, belong to this group.

The outline of the ancient lake-basin in which these strata were deposited is not fully determined, but there are indications that its eastern boundary was outside of the present limits of the Green River Basin, and there is no room for doubt that the Uintah Mountains and the Wahsatch chain then, as now, towered above its surface. Northward it is equally clear that the Wind River range formed the shore of the great lake, with probably more or less of gently sloping border during a portion of the era of Lower Eocene deposition. This formation is now exposed over our route from Fort Bridger to near South Pass, the excessive erosion over this area causing the rocks to be laid bare in most places, so as to afford favorable opportunities for study, but they do not yield as plentifully the interesting remains which are characteristic of these beds in the neighborhood of Green River City, though it is highly probable that rich harvests will hereafter be reaped by collectors who may be able to examine the outcrops with some degree of thoroughness.

Generally speaking, the rock contains a considerable portion of calcic carbonate, with an abundance of ferric oxide produced by decomposition and oxidation. *Gypsum* and *calcite* of different varieties are abundant, frequently occurring as thin, papery seams between the rock-layers, at other times forming masses of considerable extent. These features are scarcely as characteristic of this formation, however, as of the Bridger group. Some of the layers are little more than a pure clay shale, while there are a few quite arenaceous beds and some compact limestones. The mineral peculiarities are so generally the result of chemical and other changes in the rocks of a secondary nature, that they will be more properly considered in that part of the report which treats of the action of atmospheric agencies, under the general head of dynamical geology. The texture of the different beds is quite variable, but, in general, the streams which have cut their channels through them are walled by nearly vertical cliffs, and the buttes and benches for the most part have quite precipitous sides. Numerous joints occur in many of the strata, particularly in the more compact kinds, and fine examples of concretionary structure or weathering are not rare. The tendency of the thick beds of marly sandstone on the banks of Green River, at the crossing, to weather spheroidally is very noticeable, and this is repeated in various degrees in the argillaceous and calcareous rocks as well.

Organic contents.—In the absence of adequate knowledge of the affinities of the fossil-plants collected, it is impossible to state with certainty their bearing upon the age of the beds now under consideration. Indeed, after the abundant material of this nature which has passed through the hands of Dr. Newberry and Professor Lesquereux, it is scarcely probable that the meager collections made by myself in 1873 will furnish cause for the changing of opinions so strongly held by these vegetable-paleontologists. Some remarks regarding the manner of occurrence of these remains will, nevertheless, not be out of place. The finest specimens were obtained from an exposure in a bluff just below the stage-station at First Crossing, Big Sandy, on the left bank of the river, near the top of the bluff. A few good specimens were obtained from a cliff upon the left bank of Green River, about one mile and a half below the crossing at Robinson's Ferry. Outcrops of plant-beds at other localities were not rare, but the remains were seldom as well preserved as in these places. The rock containing these is usually a very fine-grained white or yellowish shale, often more or less ferruginous. The leaves, the most common form in which the relics exist, are mostly spread out smoothly, giving most perfect impressions of the ribs and veins, making their identification a matter of comparatively little difficulty. In some places the plant-layers are composed of comminuted fragments of leaves and other vegetable matter crowded together in an indefinable mass, and again mere bits of water-worn pieces were scattered thinly over the shale, seldom sufficiently distinct for determination, while even more frequently the shales are traversed by irony streaks of ferric oxide, without a trace of the original vegetable tissue.

The animal remains gathered during the summer of 1873 are mostly well preserved, consisting mainly of Lamellibranchs and Gasteropods, of the genera *Unio*, *Corbicula? Melania*, *Viviparus*, and *Turritella?* with possibly others, including, perhaps, some undescribed specific forms. In a bluff on the right bank of Ham's Fork, less than half a mile below the old toll-bridge at the main crossing, a bed remarkably rich in *Unio*, associated with immense quantities of *Viviparus*, occurs, half way to the top, directly above the stream. Directly opposite Camp 3, on Muddy Fork, a few feet above the water, there is a bed almost completely made up of Gasteropods—*Melania*, *Vivipara*, and *Turritella?* This is but a few rods north of the Union Pacific Railroad. A somewhat similar

Gasteropod bed underlies a thinner layer, apparently almost wholly made up of *Cypris* remains, which is exposed on the left bank of Black's Fork, a few rods below the lower bridge across that stream at Fort Bridger. This exposure is near the point at which the telegraph-line to Carter crosses the creek. Back in the cliffs, on the right bank of Green River, nearly south from Camp 6, (three miles above Robinson's Ferry,) in a thin calcareous shale partially saturated with *petroleum*, I obtained a single specimen of the vertebra of a fish. This bed is probably of the same horizon as the petroleum beds not far from Green River station.

In the present state of geological science, there are few who will not acknowledge that vertebrate remains are a better criterion of the age of a formation than fresh-water molluscs, or the leaves of plants. No one doubts that the beds of the Green River group are Tertiary; and more recent beds, with abundant remains of the higher vertebrates, being referred to the Eocene by the best authorities, it will be seen that the reference of the Green River strata to the Lower or Middle Eocene is tolerably well founded. This classification receives additional support from the statement of Prof. E. D. Cope, before given, concerning the affinities of the fossil fishes collected from this formation near Green River City.

BRIDGER GROUP.—(Upper Eocene.)

The beds overlying those of the Green River group are closely related to them in age, for the transition from one to the other is not abrupt, whether we regard their structure or their contents. All who have had occasion to study the features of both groups, in the field or the closet, have agreed in this, that they have regarded them as representatives of a single Tertiary epoch, the point of controversy being only the question whether they together represent the Eocene or the Miocene era. After all, it will be found that the whole difficulty originated mainly in the doubt concerning the true age of the coal group beneath, the settlement of which seems just now to be the chief desideratum of American geology. Hayden provisionally referred the Bridger group to the period of the Upper Miocene, which must have been proper had the Green River group proven to be of Lower Miocene age, as he at first supposed. Those who hold to the Eocene age of the lower strata will, therefore, also be unanimous in the avowal of the Upper Eocene age of the members of the Bridger group.

This formation is exposed at the surface over a considerable extent of country, northward and eastward from Fort Bridger as far as Little Sandy River and beyond, forming the top layers of numerous isolated buttes. Along our route they are nearly horizontal or dip very slightly. Perhaps the most instructive section observed on the trip, south of South Pass, is in the vicinity of the Uintah Mountains, where the beds of the Bridger group may be seen in their connection with the tilted strata of earlier date. Figure 5 gives a general view of the structure of the country lying between Fort Bridger and the Uintah Mountains although it does not strictly represent a section in a direct line between the post and Gilbert's Peak, but, more properly, it is a representation of the principal facts with the surface features exaggerated, but mainly correct, as far as the cañon of Henry's Fork. Gilbert's Peak is then included to show its geological relations, although it is really out of the line of the section.

During the epoch of the Bridger group, it is probable that the land was covered with fresh water in a lake as large as in the previous era, if not more extensive. It may have been that the northern shore was farther south than during the time when the Green River beds were deposited, but the mere fact that few of the Bridger strata now cover the

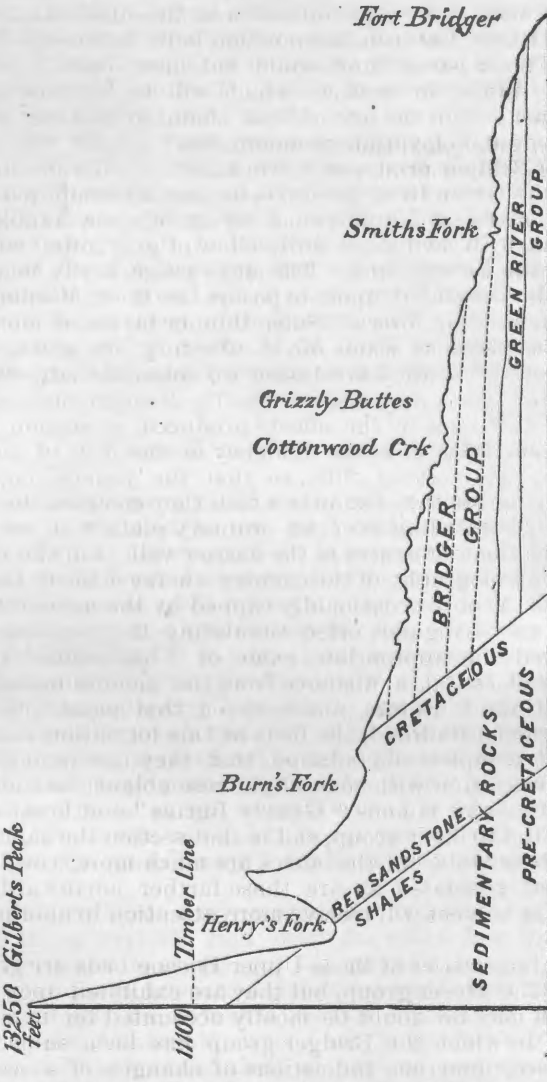

FIG. 5. Ideal section from Gilbert's Peak to Fort Bridger. Vertical scale 2,400 feet, horizontal scale (estimated) seven miles, to one inch. This section is not intended to be minutely accurate, but it shows the main features as observed in a trip from Fort Bridger to the Uintah Mountains. (See Chap. I, Narrative of Special Trips.)

underlying group north of the Little Sandy, on our road, does not afford sufficient proof of this. There is, doubtless, much yet to be learned from the field study of that section of the Green River Basin, as yet unexplored geologically, which lies north of the forty-second parallel and west of longitude 109° 30′. It may, however, be safely stated that the lake of this epoch did not extend across the divide of the Wind River Mountains. There is also no doubt that the Uintah Mountains formed a portion of the southern boundary, though Professor Marsh discovered evidence of a synchronous basin south of this range, which, having been much lower, may have received the outflow from the ancient Bridger Lake, though he remarks that the outlet was not through the present channel of Green River. If the Washakie group of Hayden, east of the present continental divide, be synchronous, and *continuous* with the Bridger group, the eastern boundary of the basin in which both were accumulated was far outside of the present Green River Basin, but this supposition is little more than a surmise thus far. The western limit could not have been beyond the Wahsatch higher ridges, for reasons which will be obvious to those who read the remarks upon the age of that chain, in the section treating of the subject of the elevation of mountains.

The beds of the Bridger group, as a whole, are readily distinguishable from those of the Green River group, being mainly composed of dull-colored indurated clays, and arenaceous layers of considerable thickness, the latter usually brownish, or dull yellow or gray, often with more or less of a concretionary structure. The clays are generally compacted, but they become disintegrated upon exposure to the atmosphere, and readily yield to the eroding forces. Some thinner layers of more calcareous material, with siliceous seams often affording interesting concretions, are interspersed, but they are rather exceptional than otherwise. These two groups of strata may also be readily distinguished wherever seen by the great difference in the effects produced by erosion in each case. As before remarked it is the tendency of the beds of the lower series to present nearly vertical cliffs, so that the general impression received in passing across the section in which they compose the surface formation is that of traveling over an ordinary plain with occasional descents by a succession of terraces to the narrow valleys of the streams; on the contrary, the topography of the country wherever the Green River beds are concealed or only occasionally capped by the members of the Bridger group, is very irregular, often simulating that peculiar aspect which has received the appropriate name of "bad lands" in other regions. In some places at a distance from the mountains, as in the neighborhood of Church Buttes, and between that point and Bryan along the Union Pacific Railroad, the beds of this formation have been so eroded without complete denudation, that they now stand out in buttes by themselves, often with some slight resemblance to rude architectural forms. The now famous "Grizzly Buttes" southeast of Fort Bridger belong to the Bridger group, and in that section the same essential features are observable, but the buttes are much more crowded, and seldom so completely isolated as are those farther northward. This intensely interesting subject will receive more attention in another chapter. (See Erosion.)

The mineral characteristics of these Upper Eocene beds are generally similar to those of the Lower group, but they are exhibited upon a much larger scale, which may no doubt be mostly accounted for in the more extensive erosion to which the Bridger group has been subjected, especially as there are numerous indications of changes of a secondary nature. The subject can be more appropriately discussed beyond, (see Chemical Geology,) but a brief review of the more common mineral forms will be now given. Gypsum, in the forms of *selenite*, *satin-spar*, and, more rarely, as *alabaster*, is very common. One of the most striking features of many of the buttes is the silvery, glistening appearance which they present in the clear light of the sun, giving them at a little distance a very pleasing aspect. Closer investigation shows that this is produced by the reflection from enormous quantities of bits of *selenite* which lie strewn over the surface of the slopes. When found *in situ* it usually occurs in thin layers between more extensive beds of other material, or in masses, the fibrous forms not unfrequently being rather geodiferous in their formation. Joints and planes of loose lamination are commonly filled with *selenite*, or even with gypsum in the form of small crystals, which are often ferruginous, or coated with ferric oxide. *Calcite* is abundant in several crystalline varieties, or *calc-spar*, also in other interesting forms, occurring in similar manners to the gypsum, of which it occasionally appears to be a pseudomorph. The presence of iron in considerable quantity is shown by the reddish color imparted to many of the rocks upon weathering, also by the accumulations of ferric oxide in the crevices, and in connection with imperfect organic impressions. *Pyrites* is probably commonly distributed, though scarcely ever obtained in distinct crystals. Silica, in its remarkable development in these rocks, constitutes one of the most interesting subjects which claim the attention of the chemical geologist in this section. Saline efflorescence, and the connection of the so-called "alkali" deposits with much of the history of the region, are topics which naturally fall within the limits of another portion of this report, where they will be further treated.

Organic contents.—The scientific public, at least, are already familiar with the great results which have accrued from the studies made by our vertebrate-paleontologists of the remains which have been obtained in such great abundance from the beds of the Bridger group, more especially from the vicinity of the Grizzly Buttes. The organic remains which I have myself obtained from these strata are not numerous, but they were obtained from new localities, as a rule, and may embrace one or two new specific forms, though this is quite doubtful. From a ruggedly weathered exposure of loosely compacted sandstones and conglomerates, with some harder beds of white and slightly red sandstones, half a mile northeast of Camp 10, on Little Sandy River, some poorly preserved specimens of gasteropods (*Melania?*) were collected, with numerous small fragments of turtles, which were found partially imbedded in the soil upon a small raised flat. At the foot of a prominent butte standing entirely alone near Soublette's road, three miles or more back from Camp 10, across the Big Sandy, a fragment of a costal plate of the carapace of a *Trionyx* was obtained from about the same horizon. B. D. Smith, one of our guides, who had collected for Professor Marsh, brought from a locality above Camp 10, on the Little Sandy, at nearly the same level, a caudal vertebra of a crocodile, a portion of the ilium of a turtle, and the proximal extremity of the left humerus of a turtle. Much higher in the series specimens of *Planorbis* were collected from a bluff exposure at the foot of the Uintah Mountains west of the Grizzly Buttes. It was possible only to collect from these beds, in the most superficial manner, but enough was observed to convince the writer that a richer harvest than has yet been reaped awaits the future collectors in this field.

CONCERNING THE AGE OF THE WIND RIVER TERTIARY DEPOSITS AND SOME OTHERS.

During one or more of the long Tertiary epochs, there was deposited over the space included between the Wind River and Owl Creek ranges, a lacustrine formation of great thickness, composed of beds of arenaceous and argillaceous material. The general character of the strata is, on the whole, more like that of the Bridger group than that of the Green River beds, and yet the formation cannot be said to closely resemble the former, nor would such a similarity between the two series in lithological features furnish, in itself, the least proof of identity of age. The sandy marls of the Wind River deposits are frequently variegated, *i. e.*, bands of a bright red or a pinkish color are associated with the blue, greenish, and light-colored beds of this material. But few fossils have ever been obtained from this formation, and it will be wise to make no definite statement regarding its age until it has been more carefully studied. The whole group lies in a nearly horizontal position, and the erosion has been so extensive that the beds are well exposed for observation, provided one can regulate his course so as to seek the most favorable localities; hence it may be hoped that the future development of this region may greatly add to our knowledge concerning them.

The arenaceous nature of most of the strata, and the oblique lamination of the sandstones and conglomerates, prove that they were deposited in quite shallow water; and these facts will account for much of the lack of organic remains. The thick deposits, on the other hand, of more alluvial material, would suggest the probability of the preservation of some vertebrate remains. Hayden has reported the discovery of fragments of the skeletons of *Trionyx* and *Testudo*, but diligent search along our route was unrewarded by the sight of a single bone of any kind. It is proper to mention here that a more definite statement concerning these beds, published elsewhere,* was based upon the supposition that some underlying beds, now believed to be Cretaceous, were of Tertiary age.

In the same unsettled state must be left the Tertiary beds which are exposed north of the Owl Creek Mountains, of small extent at present, but in many respects resembling the Wind River deposits. There is here, however, stronger proof that these are of later than Eocene date, and it may be suggested that the Wind River deposits may prove to have been laid down nearly simultaneously, but certainly in a separate basin.

In all of these beds there is an absence of the great deposits of *gypsum* and *calcite*, as would be readily supposed from their arenaceous character. The topography, also, is different, from a similar cause, although the erosion has been great, and interesting forms have been produced.

PLIOCENE DEPOSITS.

In the neighborhood of South Pass, extending across the water-shed, is a deposit which apparently represents the closing scenes of the lake period in the Green River Basin. It would seem that during the Miocene epoch, or near its close, while, perhaps, extensive but shallow lakes existed in the Wind River Valley, a portion of the Sweetwater Valley, and north of the Owl Creek range, the waters upon the western slope of the Rocky Mountains had so far been drained off as to allow of partial denudation of the old lake-bottom. During the next epoch (Pliocene) a shallow lake spread over the northeastern portion of the Green River Basin across the outlying metamorphic ridges, and connecting with a body of fresh water which more or less covered the area occupied by the Miocene (?) lake of the Sweetwater Valley. Figures 6, 7, and 8 are intended to explain this idea, without giving the slopes, elevations, or distances with any degree of accuracy.

It should be understood that the Pliocene deposits are represented as if local, merely because their boundaries are not known positively. In these deposits in the Sweetwater Basin, Dr. Hayden has obtained fos-

* In a paper "On the Geology of Western Wyoming," in Amer. Jour. Sci., vol. vi, December, 1873.

sils which show close relation to those of the Niobrara River beds of Pliocene age. On the left bank of Little Popo-Agie River, some distance below the entrance of Deep Creek from the right bank, there is a similar deposit of marls and laminated sandstones and conglomerate to that near South Pass, which may be of Pliocene age. The South Pass beds, as shown in Fig. 8, cross the outer portion of the metamorphic rocks, and some of the beds contain pebbles from those beds of the mountain nucleus.

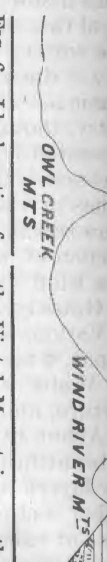

FIG. 6.—Ideal section from the Uintah Mountains northward during the *Eocene* epoch.

FIG. 7.—Section (ideal) of the same country at the close of the *Miocene* epoch.
N. B.—The additional strata here shown in the Green River basin are supposed to have been deposited before the beginning of the Miocene. In the other basins they are, *perhaps*, all of Miocene age.

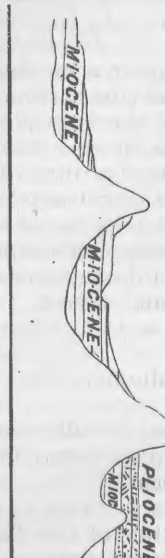

FIG. 8.—*Supposed* section at the close of the *Pliocene* epoch. The wall A, or the southern shore of the Pliocene lake in the figure is entirely *ideal*, the deposits of this age being more extensive over the Green River Basin, but the outline of the lakes (or one great lake) not being determined.

The deposits in the Yellowstone Lake Basin and in the valley of the main river and its tributaries, which may be regarded as Pliocene, are mainly the sediments of an ancient lake, of which the present body of water is the representative on a much reduced scale. Beautiful and highly instructive sections of the old beach formations are exposed in the valleys of the streams, particularly in the lower valley of Pelican Creek, and far down the Yellowstone River, where they become more complicated, but on that account all the more interesting. An examination of these shows that the lake formerly extended over a much larger area, and that it has held its place amid changes of great importance. It is impossible for the most enthusiastic and imaginative person to go beyond the truth in the description of the remarkable events which are here recorded in this one page, as it were, of the world's history; but this is but the beginning of the end, for the mind, even of the careful observer, fails to grasp in its entirety the vastness of the variety which is here displayed.

It was during the later portion of the Tertiary age that much of the volcanic activity took place which was so general over this portion of the country, though probably only the closing stages of the lava flows are represented by the eruptive deposits of the Pliocene epoch. As it will be necessary to speak somewhat in detail of the history of those accumulations in a section specially devoted to the subject of volcanic action, a mere *résumé* of the deposits of Pliocene age will here be presented. A section of the lake sediments, taken on the present lake-shore, between Bluff Point and Steam Point, is as follows in descending order:

1. Grass-covered soil passing gradually to loose sand, 2 feet.
2. Various sand, gravel, and spring deposits, with scattered irony concretions, 6 feet.
3. White and dark lake sand, very thinly laminated, with beach structure, and occasional irony layers, 5 feet.
4. About 15 feet of thinly laminated, blue-black clay, locally contorted and beautifully cut by a small rill emanating as a spring from one of the irony layers in No. 3. The water is slightly chalybeate.

Other sections in this vicinity show the same general features with more or less of variation. They represent the upper portion of the Pliocene series, deposited toward the close of the era of volcanic activity, hence the occasional beds of volcanic ejectamenta which were poured out into the lake are mainly composed of volcanic sand and the finer textured conglomerates, as may well be seen near Steamboat Springs. As we descend the valley of the Yellowstone River we find the lower members of the group well exposed and the beds of unmodified* non-molten material becoming more common, with increasing proportions of the molten or lava series, until the latter are almost universal, and doubtless represent an earlier period, though frequently largely concealed by the subsequent spring deposits. Near the close of the Pliocene epoch the internal fires had so far died out that the igneous ejections were of fitful occurrence, and geysers, solfataras, fumaroles, &c., abounded to an almost incredible extent, giving rise to enormous deposits of siliceous and calcareous material, which has continued to be deposited with decreasing vigor until the present day. From the nature of the circumstances under which these rocks were deposited but few fossils will be expected, and yet there are some interesting facts which lead to the belief that not a few organic remains now entombed in these strata are really the relics of the Pliocene epoch and not of an earlier date. For a more complete elaboration of this and other subjects of great interest connected with this group the reader is referred to the dynamical portion of this report.

* The term *modified* will be a convenient one to apply (as in the case of drift deposits) to those lake or stream deposits which have been re-arranged by aqueous action, after having been deposited in beds by eruption from volcanoes. *Unmodified* in this sense applies to beds of volcanic sand and ashes thrown out into a lake without subsequent re-arrangement.

CONCERNING THE AGE OF THE COAL OR LIGNITE GROUP.

It is not pretended that the true horizon of the contested coal series is to be settled by the scraps of evidence which are now brought together, nor is it probable that the little that the author can present in the shape of newly obtained facts, will materially aid in promoting a decision of the mooted question. The least that can be done, however, is to place on record the field-notes of the writer, as far as they may bear upon the subject, and to show the grounds upon which they have been referred to the Cretaceous epoch in this report. It would be presumptuous to attempt, from so few opportunities of observation, to solve a problem

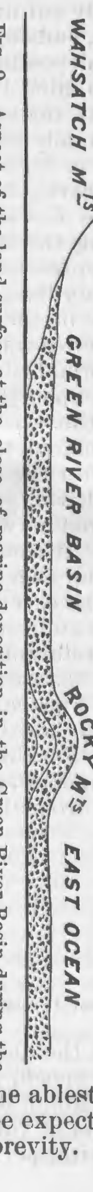

FIG. 9.—Aspect of the land-surface at the close of marine deposition in the Green River Basin during the Cretaceous epoch.

FIG. 10.—Supposed surface-features (sub-aqueous) after the deposition of the Green River Basin brackish-water beds during the Cretaceous epoch.

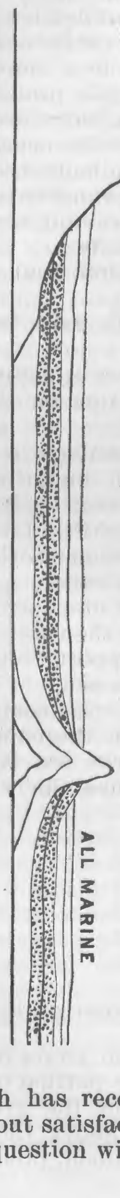

FIG. 11.—Supposed physical geography of the sub-aqueous (partly) land-surface during the deposition of the fresh-water Cretaceous beds over the Green River Basin.

which has received the thoughtful consideration of the ablest minds without satisfactory settlement. It will, therefore, not be expected that the question will be treated here, except with extreme brevity.

The investigations of Clarence King, in particular, have shown that the westward continuation of the known Tertiary strata of the Green River Basin is in a series of broad folds, and that the beds do not lie horizontally, as is the case farther east. It has also been determined that the Eocene series is there unconformable to the underlying coal group, while the latter rests conformably upon the rocks of undoubted Cretaceous age. Again, the formation of the coal was begun during the Cretaceous epoch, probably while the Rocky Mountains were slowly rising, and several lignite beds were deposited during the marine era. It is not difficult to believe that the elevation of a prominent chain in the eastern ocean, which then beat upon the flank of the Wahsatch, would gradually cut off the Green River Basin from free communication with the sea, causing it to be occupied by a brackish-water estuary, while marine deposits were still accumulating in the east; for it must be borne in mind that the Unitah Mountains then existed as a prominent range, as remarked by Clarence King. Continued gradual elevation would finally completely shut off the estuary basin from the ocean by raising it higher, when the liquid contents would gradually become fresh, provided that the outlet was not closed, as would probably be the case, the elevation being gradual. The three accompanying sections will show the idea more clearly, although some of the beds are necessarily represented as unconformable because it is impossible to show in a drawing the gradual nature of the upheaval. Subsequent to the deposition of the fresh-water beds here referred to the Cretaceous, the whole series was disturbed westward, and the Tertiaries were afterward unconformably deposited upon them. The question must at length be decided upon the evidence furnished by the organic remains, no doubt; but in the absence of conclusive evidence of this nature, it is not unreasonable to suppose that such marked physical changes as took place after the deposition of the fresh-water beds which underlie the Green River group, would have been unnaturally local if they had transpired between two of the fresh-water sub-epochs of the Tertiary period. It would certainly be difficult to account for the deposition of the estuary beds in the Green River Basin without the existence of a sea to the eastward at nearly the same level, and in view of all the facts thus far collected, to the writer at least, the belief that the coal-group is of Cretaceous date seems much less difficult to support than the opinion that the strata were formed during the Eocene epoch.

It is unnecessary to make more special mention of the coal-beds which, it has been previously observed, are exposed in the cañon of Buffalo Fork of Snake River, for the foregoing remarks are largely based upon a study of that section, and no special features have been elicited from them.

CHAPTER V.

STRATIGAPHY, CONTINUED.

Post-Tertiary and recent Glacial and Champlain epochs—Terrace epoch.

From the numerous organic remains entombed in the strata of the Eocene epoch, we learn that the climate over a large portion of the Rocky Mountain region was tropical or subtropical; but the gradual elevation of the mountains to a considerable distance above the sea-level, with, perhaps, other causes now too little understood, produced also more or less gradual changes in the climatic conditions. Hence we find that the plants and other relics collected from the Miocene beds indicate a climate cooler than that of the Eocene epoch, though milder than that of the present day. This condition of things continued with little apparent change during the Pliocene epoch, or until near its close. In Eocene times there roamed over the western continental hills and plains vast numbers of peculiar mammals, and in the dense forests innumerable birds filled the air with sonorous notes, while reptiles of the most varied forms sought the darker recesses of the murky swamps, and fishes and molluscs in wonderful variety inhabited the great fresh-water lakes. Then was presented a scene in many respects similar to what may now be viewed in some of the more elevated portions of the tropics where lakes abound, but on a scale more vast than has ever been witnessed by human eyes. The "struggle for existence," ever more severe in tropical regions than in milder climes, resulted in the destruction of millions upon millions of individuals, the remains of which, as Dana remarks, are now coming to a new "existence" through the researches of our eminent paleontologists. Slowly but steadily the growing severity of the climate doubtless compelled the dominant forms to maintain their positions by successively more vigorous contests until they were finally compelled to seek the lower latitudes nearer the sea-level, and finally to succumb to their inevitable fate when the climate had reached the climax of severity, thus forcing them into a small area southward. Dr. Newberry (Hayden's Report on Wyoming, 1870, p. 337) has well suggested that exposure to such vicissitudes would have less effect upon some of the more hardy plants than with animals, on account of the smaller space required by the former for support; hence, as he concludes, the cause of the greater similarity of our flora than of our fauna to that of the Miocene epoch. The rise of the land continued during the Pliocene epoch, and the more elevated lakes were gradually drained, thus adding to the increasing rigor of the climate. There are probably few who will insist, after a careful study of the facts, that the period of extremely low temperature which undoubtedly succeeded the Pliocene epoch, was wholly the outcome of the mountain elevation. However this may be, this is not the place for discussing the influence of cosmical causes in bringing about the results which followed. We will, therefore, turn our attention directly to the main features of the deposits of the more modern periods, without here entering deeply into the subject of the forces employed in their accumulation.

POST-TERTIARY, OR QUATERNARY SYSTEM.

We have now reached a point in geological history beyond which it will be impossible to divide the separate formations into so many distinct and related groups, and we shall find, as we proceed, that we have entered upon the discussion of a series of events of a more modern character than those which have preceded, many of which still continue with diminished energy and effect. The close of the Pliocene epoch left the country in the neighborhood of the mountains in a partially exposed condition. During all the previous periods erosion had taken place upon a grand scale, but the material transported had been only removed to short distances from the mountain eminences, and it was then accumulated at their bases in such a manner as to add largely to the elevations of the surrounding plateaus. The streams were so small and so swollen at intervals by large lakes, not remarkably high above the level of the sea, that their erosive power was comparatively slight, except for short distances. It is probable that the lakes were fed by numerous small tributaries from all sides, rather than by one large inlet receiving the contributions of many branches.

The draining of the lake basins, and the elevation of the land, with the accompanying decrease of temperature, would increase the amount of erosion by giving greater slope to the surface, and by combining more extensively into river-systems the hitherto independent streams. This would also be facilitated by the precipitation of the moisture as snow in the place of rain, as before. Such, in brief, were the conditions at the close of the Pliocene epoch.

GLACIAL AND CHAMPLAIN EPOCHS.

Evidences are not rare in the west, north of the 41st parallel at least, of the former existence of a period during which there occurred the principal phenomena which have had such an important influence in shaping the surface-features eastward. However difficult it may be to fully account for the important climatic changes which succeeded the Tertiary period, there is now no reason to doubt that the Pleistocene, or Post-tertiary period, was opened by an epoch of frigidity with a climate similar to that of the subarctic regions at present. In seeking for the causes of such an apparent difference in temperature between these contiguous eras, it is necessary to bear in mind the fact that the cold of the glacial epoch was universal over the northern portion of our globe; hence it is unnecessary to suppose that that portion of the Rocky Mountain region lying south of the forty-fifth parallel was elevated much, if any, higher above the level of the sea than in the Pliocene epoch, for the extreme severity of the climate farther north would have had a chilling influence upon the temperature in the lower latitudes. Judging from the observations of others southward, it is concluded that the lower limit of the ancient glaciers of this age in the west was not far from its latitude in the east, *i. e.*, about 39° N., or in Colorado, near the latitude of Pike's Peak.

Inasmuch as the drift-deposits in many portions of the Rocky Mountain chain are often of comparatively small extent, and usually bear evidence of transport for short distances only, it would seem that the glaciers from which they came were more local in character than were those which then existed farther to the east. Dr. Hayden, whose opportunities of observation have been very extended, has repeatedly remarked in his reports that he has "never been able to find any evidence in the Rocky Mountain region of what is usually termed a northern drift."

There is, however, little doubt that the glacial deposits in this section are synchronous with those which exist in the east, and it is the opinion of the present author that the causes of the actual differences can mostly be explained. This will be rendered more plain as we proceed; but, first, it will be well to take a cursory glance at the deposits as they occur in Western Wyoming.

In passing southward from Fort Bridger toward the Uintah Mountains, the buttes are frequently found covered with small fragments of various rocks, which are quite firmly imbedded so as to resemble a variegated pavement. Many of them represent the more recent formations, being largely siliceous, and these may owe their present position to the action of water, or other causes, not entirely during the glacial period, which is probably the case when found upon the terraces of the streams.

Associated with these in many places, however, are undoubted drift-pebbles, composed of materials from the earlier strata, and deposits of the finer and coarser mixed gravels of considerable thickness are not infrequently exposed along the banks of the streams. The remarkable extent of the erosion over the Green River Basin, and its relations to the surrounding mountains, make it unsafe to generalize upon all the phenomena of the Drift period in this section, without extended observation of the facts; but it may be said that the features already mentioned rapidly increase in importance as the Uintah Mountains are approached, showing clearly that much of the material was transported from that direction. Much of the structure of the Uintah range, particularly near the line of junction between the tilted strata and the nearly horizontal Tertiary beds, is obscured by very thick deposits of drift-material, and the harder formations of the outlying ridges have been eroded into rounded hills by glacial agency, as is shown by the quantities of bowlders which are strewn over their summits and down their sides.

Northward from Fort Bridger the drift-deposits seem to thin out, and finally almost to disappear until pebbles of the metamorphic series begin to be seen beyond Green River, and they gradually increase in size and amount northward to South Pass, in the vicinity of which some of the rounded hills of Pliocene strata are covered with numerous heavy bowlders. One mile south of Dry Sandy Creek a bowlder thirty inches in diameter was observed lying over beds of probably Eocene age, though now well imbedded in the soil. The water-divide at South Pass is composed of Pliocene rocks, which were deposited in a lake which covered the upturned edges of the metamorphic group, and it is evident that the erosion of the valley of the Sweetwater, in at least a portion of its extent at this point, was accomplished during the glacial epoch, for the stream has since, in some places, cut its way through the drift-deposits. Over the district from South Pass to Camp Stambaugh, the erosion has been great, and numerous local valleys have been formed, many of which are now filled in with moraine-deposits, or occasionally with modified drift. Bowlders are scattered over the surface in many places, but they are, perhaps, less numerous than might be expected. Between South Pass City and Camp Stambaugh, particularly near Atlantic City, a very fine road has been laid out through the accumulations of the fine material, and over several quite large moraines.

Much drift, composed of quartz, quartzites, and a great variety of fragments of the metamorphic rocks, largely covers the slopes of the hills above Beaver Creek. The two forks of Twin Creek are separated by part of a moraine, jutting out from the hills in a direction nearly northeast, (N. 40° E.) Deep Creek Valley (Red Cañon, see Fig. 4,) was probably cut during this epoch, and it was then partially filled with the detritus of the Triassic brick-red sandstones, which was modified by the action of the water. Between the Little Popo-Agie and the North Fork of the Popo-Agie River erosion has been extensive, and heavy drift-deposits occur. The same may be said of the country lying between North Fork and Camp Brown, where these features are noticeable on a larger scale. On the trip from Camp Brown to Chimney Rocks, described in Chapter I, the evidence of ancient glacial action was abundant. At intervals along the northeastern slope of the Wind River Mountains, the various streams emerge from the mountains through narrow cañons with nearly vertical walls hundreds of feet in height, but an examination of the country inside of the great ridge of limestone of the Carboniferous age shows that each of these cañons receives the accumulated waters of several prominent tributaries which rise in the mountain nucleus far to the northward or southward. Moreover, the higher points of the nucleus stand as islets hundreds and often thousands of feet above th sources of the streams at their base. Clearly, then, we have here complete proof of an amount of erosion since the elevation of the range which, without this evidence, would seem almost incredible. But this is but a small part of it, for there are in this section magnificent and extensive parks; long and high moraines, composed of huge granitic bowlders, stretch like vast walls across the way, with intervening lakes or ponds; scattered bowlders of other material, and immense blocks of the tougher sedimentary strata of Silurian age, are to be seen in the greatest profusion; yawning chasms many hundreds of feet in depth have been scooped out of the very summits of the highest ridges, and the numerous water-courses now follow channels which they could never have cut for themselves.

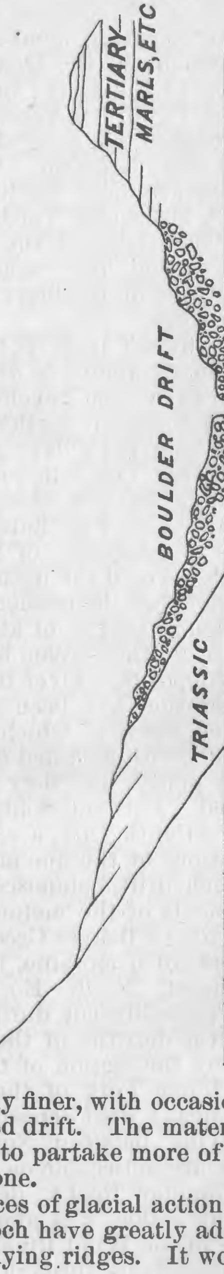

Fig. 12. Section across Wind River above the junction of North Fork. The outline of the surface below the bowlder drift is ideal. The formations lying between the Triassic and Tertiary systems are not exposed.

The deposits of the drift are in general abundant across the Wind River plateau, decreasing in amount toward the main stream until an increase is again apparent upon approaching the Owl Creek Mountains. Northward from Camp Brown the coarser bowlder ingredients are more common, and the streams which flow out from the Wind River range, including Bull Lake Fork, are often seen passing directly to the main river by continuous cañons, at right angles to the trend of the mountains. Such streams are usually bounded by heavy deposits of drift-bowlders, composed of granitic and metamorphic rocks from the nucleus of the Wind River range. Frequently these accumulations are found filling large hollows which had been previously eroded in the Tertiary and lower stratified rocks, and in one case the valley of Wind River has been cut for some distance through an extensive deposit of this nature. This is shown in Fig. 12, which represents a section across the main stream, between the mouths of North Fork and a smaller stream from the right bank a short distance above.

Passing up the Wind River Valley from this point the materials are found to become gradually finer, with occasional exposures along the river-banks of some modified drift. The materials also appear to change character somewhat, and to partake more of the nature of the volcanic rocks of the Sierra Shoshone.

To return to the Owl Creek range: The evidences of glacial action are not rare, and the erosion and deposits of this epoch have greatly added to the complications in the structure of the outlying ridges. It would appear that the greater effect has been produced upon the northern slope, although it is often much less rugged than upon the southern side. As good a place as could be desired for the study of the dynamics of the early Quaternary period is the region inclosed by the trail of our party during the two months' absence from Camp Brown. The remarkable cañon of the main stream of Owl Creek, far more deserving of the name of river than three-fourths of the larger streams of the district, now undoubtedly marks the course of a former glacier of great power, for the remains of the ancient drift-deposits are abundantly exposed in many places along its borders, where they have been cut through by the stream. The same may be said of many other channels originating in the Sierra Shoshone, and in lesser degree of nearly all the minor or secondary water-courses, but it is only when we pass across to the main upper tributaries of Snake River that we can form an adequate idea of the enormous amount of the material which must have been worn away during the glacial era. In numerous places between the Two Ocean Pass and the Tógwote Pass, the finer materials of the drift are well exposed in sections along the streams, showing that a formation at least 500 feet in thickness was deposited during this epoch.

The study of the Rocky Mountain drift, when it can be entered upon without special regard to other subjects, will fully reward those who may undertake it. It would greatly exceed the limits of this work to attempt anything like a complete discussion of its history, and the most that can now be done is to give very briefly an outline of the author's conclusions so far as they seem warranted by the facts. We must believe, from the enormous thickness of the Tertiary strata which were deposited at the base of the higher elevations, that the denudation which had been produced at the beginning of the Quaternary period was very great, and this view is well corroborated by the records which have come down to us. Before the close of the Miócene epoch the anticlinal of the Wind River Mountains had so far been eroded that the Sweetwater Basin then, as now, formed a portion of the Atlantic drainage system; and the same is true of the Wind River Basin. The Green River Basin during at least the latter part of the Eocene epoch was occupied by a lake which probably shed its water into the Uintah Basin, though by a different channel from that of the present Green River. The existing cañons through the hard limestone ridge upon the northeastern slope of the Wind River range were doubtless begun during the Cretaceous period, toward its close. We may, then, with good reason suppose that a section across the main chain at the beginning of the glacial epoch would be essentially as indicated in Fig. 13 by the broken line. The dotted lines may be taken to represent, in a general way, the relative positions of the bed of the main branch of Little Wind River along its course through the mountains, though it is obvious that this cannot be done with great accuracy. It would require a dozen sections to show the variations in the transverse outlines of this range at different points, but it is believed that the most prominent features are fairly exhibited in the accompanying figure. Leaving the reader to supply the details of the argument from the facts which have already been given, it may be remarked that the conclusion seems natural enough that the main glacier of this region followed a course very nearly coincident with the axis of the range, probably gradually increasing in size, from a mere cap at the summit until it had spread so as to fill a large portion of the space between the flanking Carboniferous ridges, thus wearing for itself an irregular channel in a southeasterly direction. At various points along its sides the material inclosed in the ice was separated from the main glacier and carried down into the plains and distributed. There is also some reason for believing that the northeastern slope of the mountains was in many places denuded by glacial action so as to leave small lakes outside of the limestone-ridge, or, perhaps, one or more larger lakes, with very irregular outline, and quite uneven bottom, in which the bowlders and finer material were deposited. Be this as it may, there is abundant evidence that the glacier escaped over this edge of the range at several points.

For my own part, after the careful review of a large number of facts, collected at every point along our route, I am disposed to regard the period of drift-deposition, over a considerable portion of the Rocky Mountain region, as made up of two epochs, and it is highly probable that they were nearly synchronous with the Glacial and Champlain epochs in the east. This view has been adopted in the arrangement of these deposits in the Stratigraphic Chart accompanying Chapter III. To express this idea more clearly, but much too briefly, it is probable that the Pliocene epoch was followed in this section by a gradual diminution of heat, which caused the lower limit of perpetual congelation to descend by degrees from near the summit of the mountains.

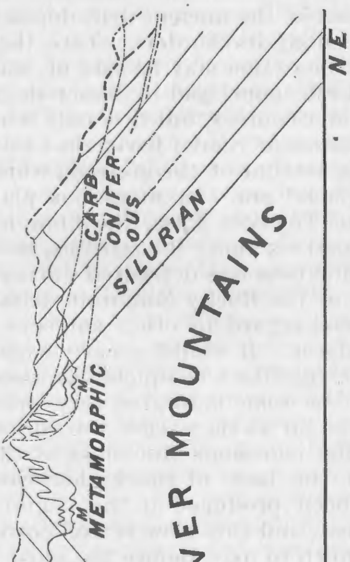

Fig. 13. Ideal section across the Wind River Mountains. The broken line represents the outline at the beginning of the glacial epoch. The lower unbroken line gives the present outline. The surface-features of the northeastern slope were obtained on the trip to Chimney Rocks, and those of the southwestern slope are partly made to correspond, though probably different *in detail*. The drift deposits are not shown, except the moraines, which cover the metamorphic series at M M. The darker crumpled line represents, roughly, the outline of the central portion northward.

The first erosive effects were therefore produced near the axes of the ranges, and the courses of the channels produced in each case would very largely depend upon the surface features, but with a prevailing southern direction. At first one of the great causes of glacier motion—the difference between summer and winter temperature—would probably be almost wanting, but this would also continue to increase, though perhaps never becoming so great as in many other parts of the country. For a long time the erosion of the tilted strata remote from the axes would be accomplished by water from the melting snows, and thus channels would be cut and the river-courses upon the plains would be marked out. As the snow-line came nearer the plains the glacial action would become apparent also; and still later smaller side-glaciers would, doubtless, partly follow the larger valleys or cañons, widening them and often slightly altering their courses. Through some of these valleys and in places over the ridges through which the water-cañons had been cut, some portions of the main glacier would finally escape. It might happen that one of the side-glaciers would dam up the main valley below the mountains, forming a lake above itself, which would distribute the bowlders and finer material according to size. In places along the Wind River Valley, above Lake Fork, this feature is displayed, and elsewhere in the narrower portions of other valleys. Later still, the melting of these ice-streams gave rise to accumulations of fine and coarse materials which were afterward re-arranged by the streams, according to the force of their currents, in the upper valleys usually being stratified irregularly as *modified* drift, while the very fine particles were often carried below and deposited in the undrained lakes.

To sum up, then, it is the author's opinion that these deposits may be conveniently divided into two groups, sufficiently distinct in character and origin to warrant the belief that they represent the two eastern epochs, generally known as the Glacial and the Champlain—the *freezing* and the *thawing* eras, as they may not inaptly be termed.

During the freezing or Glacial epoch, glaciers spread widely over the more elevated portions of the Rocky Mountain region, and the effects produced by them were enormous, but mainly local.

The general direction of the motion was from the northwest, but greatly modified by the slopes of the country. Erosion by water and ice was very great, and in some places immense deposits of bowlders and detritus were formed.

The deposits which I have referred to the Champlain epoch may belong in part to the Glacial epoch, for it can hardly be said that it is proper, in all cases, to separate these eras. All over the Green River Basin, in the Wind River Valley, and elsewhere upon the plains, away from the mountains, the materials of the drift are widely but thinly scattered, the particles gradually increasing in size as the mountains are approached. Thus, fine pebbles of red sandstone from the Wahsatch or the Uintah range, twenty to fifty miles distant, may be obtained from the summits of some of the higher benches north of Fort Bridger, and the metamorphic series of the Wind River range begins to be represented before these disappear. Clearly these are not the direct products of a glacier, but the facts would seem to indicate deposition by re-arrangement in the waters of a shallow lake, as Hayden has remarked. The agency of small icebergs might be suspected, but the arrangement of the materials according to size is too regular for the support of that supposition. The large isolated bowlder noticed south of Dry Sandy Creek, with some others nearer the mountains, may have been thus transported for a short distance, but these are quite exceptional. The principal reason which can at present be offered for referring these accumulations in the Green River Basin to the Champlain epoch is, perhaps, not very conclusive, but it affords some little ground for such a provisional classification. It is this: If the lake over the bottom of which they were spread, had existed during the glacial epoch, it is but reasonable to suppose that in this long period of time a considerable thickness of material of various sizes would have been deposited from the wear of the mountains, but this has not been observed; hence it is probable that this lake was a later body of water caused by the melting of the glaciers upon its borders, and the accumulation of morainal *débris*, which were assorted, as it were, according to weight, by its waters. But there are other deposits of greater thickness in various localities, which, by their position overlying the drift, show that they are of more recent date. It is impossible to do more than to enumerate them here. They are—

1. Deposits of *modified* drift of varying thickness, mostly exposed along the banks of existing or ancient streams.

2. Deposits of "till," sometimes of great thickness, evidently deposited during the melting period in the deeper portions of the lakes, or in *other* more local lakes.

3. The connection of the *graduated* drift, as it may be called, with the other Quaternary deposits in the Wind River Valley renders the reference to this age of similar accumulations in other localities more probably correct.

TERRACE EPOCH.

The transition from the Drift era, including the Glacial and Champlain epochs, to the succeeding epoch in the earth's history, was certainly not abrupt, and inasmuch as we are now dealing, as in the whole of this chapter, with surface-formations which are still being subjected to great changes by reason of their exposure to destructive agencies, it is often difficult to determine correctly the synchronism of results. Moreover, the forces which were at work during the epoch immediately succeeding the Drift era are still active, and many of them had produced such great effects previous to the Quaternary period that the glacial denudation was insufficient to eradicate them. There is no lack of proof that the present drainage-system over the southern portion of our district was at least outlined as early as the close of the Cretaceous epoch, while over the northern portion changes have probably been produced by the igneous outflows, but still the present courses of the streams are mainly through channels of ancient erosion. But even in these regions there is enough to indicate that the epoch of the Champlain deposits was followed by a period during which the valleys were cut deeper, apparently by a succession of impulses imparted to the streams, and the records of this time are now to be seen in the form of terraces which more or less regularly follow the general courses of the present river-channels. The erosion of the valleys by the stream still goes on, but there was evidently a long era in the past when this action was upon a grander scale, and to this indefinite and transitional period it is convenient to give the name of Terrace epoch.

Concerning the causes of the fluctuations of level in the stream-beds, little can be said in a work of the local nature of this report, for it is necessary to accumulate evidence from a wide extent of country, in order to fairly discuss the subject; but the author may, perhaps, be pardoned for the expression of an opinion in this place, not hastily formed, but greatly confirmed by observations in the upper valley regions of a large number of streams during our trip. There are yet a large number of geologists who, though ever ready to acknowledge the inconceivable length of geologic time when found necessary to explain many phenomena, are still prejudiced to the old theories, which refer *all* great changes in the surface-features of the earth to the action of internal forces. There is, however, a growing conviction in numerous minds that this is a serious error, and it is the candid opinion of the writer that the production of these terraces, except in rare instances, is very largely the result of external causes.

Many interesting varieties in the forms of the terraces may be observed, some of which will be again referred to when considering the subject of erosion. A few only of the more common examples will be mentioned here. In many portions of the Green River Basin, particularly in sections in which the lower or Green River group is the surface formation, the approach to the larger streams upon each side is made over a succession of extensive and quite regular terrace-benches; and in some places the same regularity is noticeable in the minor valleys. Elsewhere in this basin, and perhaps much more commonly, the surface of the terraces bordering ancient streams has been much changed, so that it is not always an easy matter to determine their courses. Fine examples of regular benches are also to be seen in the Wind River Valley and in other places away from the mountains.

Even in the gorges of the streams issuing from the rugged Sierra Shoshone, this structure is often observable, though now much obscured by the growth of trees. In the valley of the Yellowstone River, at many points, the terraces can be readily made out, but their surface is largely scored by gulleys, which cause them to appear less regular than they really are. One of the best places for the study of the effects of running water upon the beds of streams is the section of country between the Two-Ocean Pass and Tógwote Pass, where there is probably as much variety in the results as could well be found over an equal area elsewhere.

HUMAN PERIOD.

The close of the Terrace epoch brings down the history of the earth to a time when the present conditions were in force, and the changes which have since taken place are of comparatively slight extent, although much has been done in the way of denudation, transportation, and deposition, from which important local formations have not unfrequently resulted. Some very prominent recent deposits, which have been in process of formation during several of the preceding epochs, have been lightly passed over, that their history may be more clearly elucidated by comparison with similar action now in progress. Such are the hot-spring and geyser deposits, many of which doubtless originated long before the present epoch, but, being now active and of special interest from their comparative rarity, it has been thought desirable to devote one or more chapters to their exclusive consideration. It is also proposed in succeeding chapters to treat as completely as opportunity will allow of the forces or causes which have produced the effects previously discussed. It is consequently unnecessary to speak very fully of the remaining general deposits of the human period which exist in the district under consideration, for they are almost entirely the direct results of local action, which can usually be traced with little difficulty. The so-called *alkali* deposits, and the rather common dunes, mounds, and furrows of wind-blown sand, will each receive due attention in the part of the work devoted to dynamical geology, and this passing allusion must here suffice. The same remark may be made concerning the prehistoric and other relics, which will receive special mention beyond. There are not a few other topics also about which much of interest and importance might be written, such as come more properly within the scope of the science of zoology. These also must be left for review in another portion of the report, and this chapter may appropriately conclude with some—

GENERAL REMARKS ON THE POST-TERTIARY AND HUMAN PERIODS.

Whatever may have been the cause of the cold of the glacial epoch, there can be but little doubt that by some means the northern portion of the continent was raised to a considerable height above the level of the sea during the period of its continuance. The resulting glaciers extended far to the southward, causing great erosion of the surface over a very wide area, but the effects produced near the summit of the Rocky Mountains, though frequently of much importance, were usually of a local character. The general course of the motion of the ice-sheet between the forty-first and the forty-fifth parallels was about southeast, varying according to circumstances to a greater or less degree, It may be suggested—the writer is not sufficiently familiar with the facts farther south to offer it as a confirmed opinion—that the cause of the local nature of the deposits, resulting from comparatively slight glacier motion, was the gradual change of climate after the Pliocene epoch. In other words, if the decrease of temperature was almost wholly owing to the slow approach of glaciers from the north, we will suppose that the Wind River Mountain glacier, for instance, did not fairly begin its erosive action until one-third of the glacial epoch had elapsed; that is to say, one-third of the whole time during which the bulk of the glacier existed in the north. Now, we know that there was a more or less gradual reversal of these conditions during the Champlain epoch, and it may have happened that the climate at the supposed point farther north would cause the glacier there to continue as much longer as it had before preceded the Wind River Mountain ice-mass. Thus the latter would have just one-third as much time, with much less force for the performance of its work of erosion and transportation. Upon this supposition, it is not necessary that the effects produced should be found to decrease quite gradually as we go southward, for the amount of erosion or transportation effected at any one point depends quite as much upon the resistance as upon the power employed. The author must not be understood to imply by these remarks that the formation of the more southern portions of the great ice-sheet was separated from the Pliocene epoch by a greater interval of time than was the case farther north, though this may have been true. In such a case, it is more than likely that all the southern Pliocene beds are not synchronous with what might be called the *parachronous* beds farther north, using the latter term in the sense of beds of the same *relative* age.

The Champlain epoch, as a whole, was one of relative approach of the land elevations to the sea-level, and during this era the climate gradually became more mild from the diminished amount of surface above the sea. There was then a partial return toward Lower Tertiary conditions, and the valleys were partially filled with material washed from the deposits of the melted glaciers, which was afterward partly removed by the action of the streams during the Tertiary epoch. The fauna of the west became enlarged, and finally man entered upon the scene, leaving behind him relics of his rude skill, with monuments of his superstitions. Passing down thus through the prehistoric period, we next find proofs of the existence of later tribes, who have left us far too little of themselves, and by degrees we come to the present Indian families spread apart by fortune and misfortune until their tribal relations are even less understood by each other than by the white man who makes them his study.

Accompanying man, or rather accompanied by man, in his nomadic condition, large herds of ruminating animals next crowd the plains, deriving therefrom their sustenance. With remorseless hand, the wily savage drives them from their haunts, and in a few short years spreads their bones far and wide across the country. Literally exterminating as he goes, for a brief while he rules supreme, when, pushing eastward to seek the food-supply of which his reckless waste has deprived him, he is met by other tribes more savage than himself, pressed westward by a power greater than hunger—the onward march of civilization. Then begins another conflict, and the records which have hitherto been the property of the geologist and the archæologist are silently placed in the keeping of the historian, where we must leave them.

CHAPTER VI.

STRATIGRAPHY—RECAPITULATION.

General review, with economic geology—Fort Bridger and Uintah Mountains—Northward to South Pass and Camp Stambaugh—Sweetwater gold-mines—To Camp Brown and across Wind River Valley—Owl Creek Mountains—Sierra Shoshone, &c.—Yellowstone Park and return.

It is only intended in this chapter to give a very general description of the geology of the district traversed by Captain Jones in 1873, for the benefit of those who may require a concise statement of the facts in local order. In connection with this review, some few topics bearing upon the economic geology of the region will also be very briefly considered. Should fuller information upon any special subject be desired, it will usually be found more completely discussed in another portion of the report, which may readily be ascertained by reference to the alphabetical index at the close of the work.

From Creston, on the continental divide, at an elevation of 7,030 feet above the sea, the traveler on the Union Pacific Railway passes down to the valley of Green River, and beyond across the plains to the Wahsatch Mountains, over and among the fresh-water Tertiary deposits of the great Green River Basin, striking in the western portion the tilted brackish and fresh-water strata, containing large deposits of coal, which are referred in this report to the Cretaceous period. Leaving the railroad at Carter station, nearly sixty miles west of Green River City, a wagon-road is found running eleven miles southward, to Fort Bridger, which pursues an undulating course over successive benches of the lowest Tertiary formation, known as the Green River group. This represents the Lower Eocene epoch in the earth's history, and is well exposed over a wide extent of country.

FORT BRIDGER AND THE UINTAH MOUNTAINS.

Fort Bridger is pleasantly located in the well-watered valley of Black's Fork, having been a prominent station on the old overland stage-route to California. This was the initial point of our reconnaissance; but the writer was able to pass in review the country southward to the Uintah range, which forms a prominent natural boundary in this section, and it will be well to notice its peculiarities. South of west from the Post, the principal feature in the landscape is a flat-topped hill or bench, called Bridger Butte, rising to a height of more than seven hundred feet above the valley-level at the Fort. This is also interesting from the fact that its upper portion is composed of mostly arenaceous beds of the Upper Eocene formation, or Bridger group, while its base contains more calcareous beds of the Green River group. The Green River beds are exposed in part in the vicinity of Fort Bridger, and to some extent southward; but as we pass toward the mountains, the sandstones and the indurated clays of the Bridger group appear at the surface, and finally entirely conceal the underlying formation. Still farther south, the denudation has been less effective, and a great thickness of the Bridger beds is revealed in the sides of the buttes and benches. In some places, as at the locality known as Grizzly Buttes, the erosion has produced remarkable forms, and the argillaceous strata are cut through so extensively as to afford numerous exposures of their fossil contents, which are very largely made up of the remains of extinct vertebrate animals.

The Tertiary beds in the vicinity of the mountains dip very slightly, and they jut against the northern slope of the Uintahs in a manner which plainly indicates that they were deposited after the upheaval of that range. Thick accumulations of the fine and coarse materials of the drift are so common that the structure of the point of junction is much obscured; but examinations of sections at several points show that the sedimentary rocks to the close of the Jurassic period were represented in the main upheaval. The Mesozoic rocks seem to cover the underlying formations to a greater extent in the Uintah range than is common in the Rocky Mountain system.

Drift is abundant and coarse toward the central portion of the Uintahs, somewhat gradually decreasing in size and quantity northward. It is very difficult, however, without extended examination, to determine the amount of this material which may have been the result of glacial action in the Wahsatch Mountains. Accumulations of some extent exist in the vicinity of Fort Bridger, to the origin of which a hasty review of the country southward furnishes little or no clew. There are very interesting questions connected with the history of similar deposits over the whole district, which deserve careful attention in the future.

The return from the mountains is much more satisfactory to one desirous of gathering only general facts, for it enables the observer at many points to obtain views of the country extending over a wide area. The traveler across the Green River Basin can obtain but an inadequate idea of the vast amount of erosion which has taken place since the deposition of the horizontal strata, without passing down through the valleys of the northward-bound streams from the present summit of the Bridger group of beds.

FROM FORT BRIDGER, VIA SOUTH PASS, TO CAMP STAMBAUGH.

Along our route, the Bridger group is exposed at the surface over a considerable extent of country northward and eastward from Fort Bridger, and numerous isolated buttes, largely composed of the strata of this formation, are met before reaching Little Sandy River, while a number exist beyond this point, which are merely capped with these beds. Between Bryan and Church Buttes, on the railroad, there is an interesting collection of buttes which are weathered into forms slightly resembling the Grizzly Buttes, but much less crowded and irregular. The Green River beds are exposed beneath the Bridger group over the whole country north of Fort Bridger, and beyond the Little Sandy they are at the surface almost to Pacific Creek. This formation is now noted for the abundant and finely-preserved remains of fishes and land-plants which it has yielded, particularly in the railroad-cuttings not far from Green River City. A shale highly charged with petroleum is also found, containing the remains of fishes. This was met upon our trip above Robinson's Ferry on the right bank of Green River. Its fuel-properties are fair, but no economical methods of utilizing it have yet been proposed on account of the great amount of waste which clogs the furnace and smothers the fire. It is not probable that it will soon be brought into use, as the supply of better material near at hand will be sufficient for all demands for a long time.

The coal of this country occurs in a group which underlies the fresh-water Tertiaries. It is not exposed along the road between Fort Bridger and South Pass; but it is worked at several points along the railroad east and west. In the neighborhood of the Wahsatch Mountains, the strata are much tilted and the coal is easily reached. East of Green River City, the coal-bearing group is nearly or quite conformable to the overlying Tertiary series, and is occasionally found by boring at some distance beneath the surface. East of the continental divide, similar beds underlie a large area of the country, and a thriving mining-town has sprung up at Carbon station, half-way between Creston and Laramie.

Shallow-water lacustrine beds of the Pliocene epoch are seen in quantity near Pacific Springs, though not extending far southward over the plains. These have spread across the outlying portions of the metamorphic series of the Wind River Mountains near South Pass, and they have been greatly denuded since their deposition. Remnants are now left standing in the shape of immense buttes, forming prominent landmarks to the traveler in this region.

Passing northward from Fort Bridger, the drift-material thins out gradually, then increases by degrees until it is rather abundant near South Pass, its size increasing in about the same proportion. Alkali deposits, chalcedonic masses and concretions, deposits of gypsum and calcite, and interesting changes in the minor surface-features by wind and water action, are among the more important peculiarities which claim a share of the attention of those who shall make the Green River Basin the field of geological labors.

The low divide at South Pass might readily be crossed without being observed, except by the most watchful traveler; for there is no high ridge to mark the passage from the Pacific to the Atlantic waters, and the change in direction of the streams upon each side would scarcely be noticed, unless special attention were given. The water-divide is not the geological divide, or axis of the anticlinal, which is situated some little distance beyond, and is often lower than portions outside the nucleus of the mountains. It will thus be seen that the Sweetwater River rises upon the southwestern slope of the Wind River range, but cuts its way across to join the Atlantic water-system without escaping to the plains of the Green River Basin. Near the point at which the road crosses, it runs in a narrow cañon through the metamorphic slates and schists, occasionally meeting with a swell or basin filled with Pliocene strata, or the more recent accumulations of the Post-Tertiary period. Below this it meets with the fresh-water sediments of a lake which existed probably in the Miocene epoch, occupying what is now termed the Sweetwater Basin.

The metamorphic slates pass rather gradually through the common forms to the granites, which compose the axis of the Wind River range, which here constitutes the main crest of the Rocky Mountain chain. The geological divide is crossed before reaching South Pass City, and it is here comparatively low. The same gradations in the metamorphics are noticed beyond in reversed order until the overlying sedimentary rocks make their appearance upon the northeastern slope. Quartz and feldspathic seams are abundant upon both sides of the anticlinal. Heavy drift-deposits fill many of the variously-eroded valleys, and excellent roads are built without difficulty on this account. South Pass City and Atlantic City are located in deep valleys occupied by tributaries of the Sweetwater, which were in part at least cut out during the Glacial epoch, and afterward more or less completely filled with the finer drift-deposits, probably to some extent during the Champlain epoch. The Pliocene deposits extend to a remarkable distance over the metamorphic series, being discovered where wells have been dug in places where they are covered by the drift, as at Camp Stambaugh, which is almost directly upon the divide between the Sweetwater River and Wind River.

SWEETWATER GOLD-MINES.

Some opportunities of observation having occurred, the gold-mines of this section, known as the Sweetwater mining country, were examined in company with Captain Jones, with as much care as time would allow. It should be here stated that the writer is greatly indebted to the proprietors of the mines now in operation, and particularly to Mr. James Smith, of Atlantic City, for facilities given, in every case very courteously rendered and without hesitation.

The gold of this region occurs in thick veins of impure quartz among the schists and gneissic slates of the northeastern side of the anticlinal. The greater portion is disseminated through the matrix, but it not unfrequently is found in cavities in the quartz in fair-sized flakes or scales. Silver is frequently associated with it, and iron-pyrites in varying proportions is rarely absent. There are at least two prominent lodes, which may be called the Cariso and the Miners' Delight. The mining-section is locally divided into two portions, known as the Shoshone and the Miners' Delight districts. The Shoshone district, in particular, has been the scene of great excitement, and signs of comparatively recent prosperity are evident in the numerous fine dwellings, hotels, factories, and other concomitants of mining-settlements, which mark the sites of the now deserted Atlantic and South Pass cities. The mines have not been exhausted, and some are yet in operation; but so far as could be learned, the entire lack of capital and the cost of transportation of the ore to points where it can be worked, have caused their gradual abandonment or suspension. The small number of remaining inhabitants of the two cities—not more than thirty in all—are very sanguine of ultimate success, and it is quite probable that a railroad through this country would add the necessary incentive to the profitable development of these mineral resources.

The notes upon these mines, active and abandoned, will be given in order, beginning at South Pass City, in the Shoshone district. The natural facilities for placer-mining are very good, and the channels of former ditches are by no means uncommon. Some of these exist in the neighborhood of South Pass City. Numerous "prospect-holes" are to be seen in all directions.

Cariso mine.—Not now in operation. This mine has yielded well, and much labor has been spent in its working. Very good buildings, with good but not extensive machinery, are still standing above the main shaft. The shaft has been sunk two hundred and ten feet, in a tough, dark quartzite with numerous thin, quartz veins. Marshall's shaft is ninety feet in depth, and has a tunnel along the vein, toward the main shaft, one hundred and sixty-five feet in length. The vein is here four or five feet in thickness, dipping 70° to the northeast, being conformable to the adjacent rocks. Some free gold is found in the cap and wall rock, and the shafts and tunnels have been excavated partly in these. A rich specimen from the hanging-wall represents a reddish or speckled, rather friable, quartzose layer, with the gold finely disseminated. This rock very readily splits into thin laminæ upon exposure to the air, owing, doubtless, to the quantity of ferric oxide which it contains. The average of the gangue is more refractory quartz or quartzite. Iron pyrites is more or less abundant, occasionally being found in the form of cubes in the attle, or refuse. Very little water was met before reaching a depth of two hundred feet, but the reason given for suspension of the work is inability to supply pumping-machinery, which is now rendered necessary.

Young America mine.—Suspended or abandoned. Across a ravine, easterly from the Cariso mine, the Young America shaft, ninety feet in depth, has struck the same lode. Considerable silver is found in the attle, but it has never been worked, though said to exist in sufficient quantity if the more valuable gold were not present. This mine has not yielded as well as the Cariso; the average being not more than $25 per ton.

Irishman and Sheridan mine.—Not in operation at present. Two mines, consolidated under this name, have a shaft ninety feet in depth. The rock which was worked yielded fairly, but it is not extremely rich in gold. In general, it is an impure, hard quartz, but much decomposed, in parts containing pyrites.

There is apparently a "horse" in this mine, containing a considerable quantity of magnetite.

Below this mine a few rods, the Grecian Bend mine was opened, with the hope of reaching the same lode, but was finally abandoned. Tennessee, Golden Gate, and Flora are the names of other mines, which were opened and prosecuted with comparatively little success, though with fair prospects. The Barnaby prospect-pit, farther eastward, was sunk with a view of striking the lode on which the Duncan mine is located.

Duncan mine.—Worked on a small scale in summer; James Smith, of Atlantic City, proprietor. The approach to this mine, sixty-five feet in length, is roughly timbered, and its continuation in a tunnel seventy-five feet in length along the vein enters the hill about eighty feet below the summit. The mean width of the tunnel is four and one-half feet; with a large expansion or pocket, ten feet in width, near the inner end. The height is about six and one-half feet, and it slopes inward about three feet. Above this tunnel, on the hill, a shaft twenty feet in depth has been opened, with a tunnel at the bottom fifteen feet in length, striking along the same vein, and a "slope" to the surface eastward. A windlass worked by hand constituted the motive-power. A layer occurring near the middle of the vein contains an abundance of iron-pyrites and ferric oxide, mostly in small pockets. In large swellings or pockets in the vein, there occurs a soft irony layer, much decomposed, very rich in gold, most productive near the northern or hanging wall. Another hard quartzy layer is rich, and is also abundant in pockets on the side of the hanging-wall. Along the northern side of the vein, more prevalent eastward, runs a streak of quartz containing notable quantities of a blue salt of (apparently) copper, probably some silver, and much ferric oxide. An "arrastra" has been in use at this mine, and it is very favorably situated for obtaining a supply of water. The yield of gold is less than at the Cariso, but it will probably average $20 or more to the ton if properly worked.

Mary Allen mine.—Suspended. This mine is located one mile and a half eastward from the Duncan, apparently striking the same lode, which seems to turn very slightly to the north in that direction. It was not visited during our trips.

Buckeye mine.—Now being worked by McBurk, Lawn, and Dawkins. The metamorphic rocks are here nearly vertical, but the vein appears to have filled joint-fissures near the surface, making the dip of the lode at this point from 34° to 39° southwest. They have apparently, by sinking a shaft, also struck and worked another smaller vein or branch below, with much the same direction, which does not come so near to the surface. Along the upper vein, and penetrating in the same way the lower, a thin foreign seam occurs, with a fine example of "slickensides," where it comes in contact with the quartz vein. The upper vein near the surface is about nine feet in thickness. At the lower end of an incline, seventy-six feet from the entrance, it is about four feet in width, but the gangue is richer. The gold-bearing rock from the bottom of the shaft and on the side of the incline is a tough but broken quartz, with some visible particles of gold.

Between this mine and Camp Stambaugh, the Caribou mine, not far distant, and a few placer and other mines in Promise Gulch, were hastily passed for lack of time to examine them.

Young America mine, (*East End*, *Miners' Delight.*)—Now in operation. The dip of the lower wall averages 72°, S. 65° E. The shaft, which follows the vein, is one hundred and eight feet in depth; first level, sixty feet below the surface, the portion of the shaft above being on an incline. The width of the vein varies from nothing to four feet. The lower wall of the workable portion is quite quartzy, and there is much adhering quartz in many places on the hanging-wall. The average yield is about $15 per ton, and the working is easy. The proprietors run a twenty-stamp mill, and the hoisting-machinery and the timber-work are in good order and substantial. At a depth of less than one hundred feet, the shaft runs vertical for twelve feet, and then bears northward. In the center or to one side of the vein, often in pockets, occurs a blackish rock-material, which decomposes readily. At a depth of one hundred and five feet, water issues from the wall in a good-sized stream. The gold is here often found in large scales in the quartz.

The Miners' Delight district is now more thickly settled than the Shoshone district, and more or less of an impulse has been given to this section by the success of those who have opened mines. Several other prominent mines are worked, which could not be examined for want of time. These few notes give but a bare outline of the facts; but the report of Captain Jones will, doubtless, contain other items of information connected with their economy. Mr. R. W. Raymond, United States Mining Commissioner, has given these mines due attention, and he has already published more complete accounts of them.

FROM CAMP STAMBAUGH TO CAMP BROWN, THENCE ACROSS THE WIND RIVER VALLEY.

On the western slope of the Wind River Mountains, near South Pass, no signs of strata older than the Tertiary were discovered; but upon the northeastern slope many fine sections were afforded, exposing representatives of the great groups of the western sedimentary rocks, from the Silurian to the Cretaceous, inclusive. By comparing and elaborating the materials collected from various points, it is ascertained that the following formations are represented in ascending order, above the metamorphics:

1. Potsdam sandstone.
2. Quebec group limestone, &c.
3. Niagara limestone, (cherty and dolomitic.)
4. Carboniferous group.
5. Triassic red sandstones.
6. Jurassic limestones, &c.
7. Cretaceous beds.
8. Tertiary (miocene ?) beds.
9. Pliocene ? clays and soft or loose arenaceous beds.
10. Drift-deposits of glacial epoch.
11. Champlain deposits.
12. Terrace-formations.
13. Recent accumulations of blown sand, &c.

The streams flow down from the mountains by a very direct course to the plains through the sedimentary strata, including the Cretaceous and occasionally the Tertiary. A fold in these rocks is then met, which turns the more southern of the streams more or less to one side, sometimes for a short distance in a direction opposite to the general course of the Wind River. Several of these folds stretch along the Wind River plateau, being variously eroded at different points.

There are several places between the Little Popo-Agie and Camp Brown where the Triassic gypsum-beds are thus exposed in a manner which makes them quite accessible, as well as the valuable building-stone, which would otherwise have been kept concealed. Several extensive seams of coal outcrop in the Cretaceous series, and a portion of it may hereafter prove of economic value, though it is mostly of an inferior quality so far as observed. Just beyond the Little Popo-Agie, and on the Little Wind River below Camp Brown, oil-springs exist, which bid fair to become of importance in the future. That near Camp Brown has already furnished a quantity of asphaltum by its evaporation as it flows over the ground, and this has been extensively employed at the post for pavement and roofing purposes. The Hot Spring, two miles below Camp Brown, is a very interesting feature of this section, and cold sulphur-springs are found in other localities. Camp Brown itself is located in the midst of a rolling country, which has been much planed down since the upheaval of the mountains, so that the geological structure is much obscured by drift-accumulations.

The fresh-water Tertiary beds jut against the older deposits, almost exactly as those of the Green River Basin overlie the red sandstones of the Uintah Mountains, and like them they are nearly horizontal. They form the surface rocks across the Wind River Valley to near the junction of Spring and Dry Creeks, when they are replaced by the underlying strata, which are much folded and eroded, making their study rather difficult. Fine exposures of the Jurassic and Cretaceous beds are seen in the outlying ridges of the Owl Creek Mountains, with numerous fossils in the former. A species of the *Lamellibranch* genus *Gryphæa* is remarkably abundant in some of the nearly vertical Jurassic limestones. The Triassic brick-red sandstones are also exposed in places. The mineral contents of all these formations are intensified, as it were, in quality and in number of exposures by the excessive folding to which they have been subjected.

OWL CREEK MOUNTAINS, SIERRA SHOSHONE, ETC.

The metamorphic nucleus of the Owl Creek range is not well exposed, being covered, except in a few isolated localities, by the early sedimentary rocks. Glacial action and the consequent deposits of bowlders and finer material are abundantly manifested, but especially upon the northern side and in the cañons or narrower valleys of the streams.

The country between Owl Creek and the Gray Bull River is very rugged. Beds similar to those south of the Owl Creek Mountains continue. Lignite or coal, some probably valuable, iron-ore, and gypsum are not scarce. The Tertiary beds are very scanty, and it is difficult to determine their original distribution. Drift continues abundant, and interesting studies in dynamical geology, including water-erosion, wind-action, and other subjects, could hardly be more favorably presented than in this section. Cretaceous strata are most common along our route, but lower beds are occasionally seen.

From Gray Bull River to the Stinkingwater Valley, the surface is less rugged, but it still shows great erosion. No new developments of structure can be made out until the divide above Short Fork is reached, when we are obliged to descend by a very steep trail to the tributaries of the Stinkingwater. Here the volcanic conglomerate, which makes up such a large portion of the mass of the Sierra Shoshone, is seen as detached fragments scattered upon the hills, and to some distance upon the plains. An examination of the main portion as it is exposed back upon the higher ridges near Washakie's temporary camp, reveals large quantities of silicified wood, sometimes in small pieces, but often as large logs and trunks of trees. Passing beyond across Ish-a-woó-a River to the North Fork of the Stinkingwater River, more outcrops of coal are met, and a dying sulphur-spring. Near this point, a fair section is afforded, including the Triassic beds.

As we pass up the North Fork, the volcanic rocks increase in quantity, at first covering the sedimentary rocks, without obscuring them, but shortly becoming so thick that the streams have not cut to their base, thus continuing for many miles, completely concealing the structure of the original range. In fact, little or nothing was learned of the underlying rocks, while passing through this cañon, except what was gleaned from a very few exposures toward the lower end, with an occasional outcrop of some of the later strata in most unexpected places. The eruptive rocks extend westward over a vast extent of country far beyond the limits of our reconnaissance, and they constitute one of the most interesting features of the geology of the West beyond the Rocky Mountains. The cañon of North Fork has been cut to a depth of many hundreds of feet in this material.

The Stinkingwater Pass is a narrow opening between two high points on the divide between the North Fork and the Yellowstone Lake.

THE YELLOWSTONE PARK AND RETURN TO CAMP BROWN.

The geologist who reaches the park from the east, by way of the Stinkingwater Pass, will soon find his attention drawn from the study of the more ancient deposits to the consideration of the rare and too little understood phenomena attendant upon the closing stages of volcanic activity. Almost the whole tract is covered with hot springs and geysers in the greatest variety, and in many places the older stratified deposits are not visible. The Pliocene lake-deposits are very prominent, high above the present sheet of water, and they extend to a considerable distance northward, where their connection with the volcanic outflow opens a field for careful investigation. At other points, particularly northward, the earlier sedimentary strata outcrop in some cases as far back as the Silurian and even to the metamorphic rocks. Following down near the lake-shore to the river, and descending the latter for fifty miles to the bridge, one has the advantage of meeting with the facts in such order as to obtain an understanding of their significance in the best manner possible in a limited time. Then making the trip to Gardiner's River, where the hot springs are at work upon the grandest scale, he is better able to comprehend what he sees, and to apply the knowledge thus gained to the future study of the geysers in another section. It is unnecessary to dwell here upon any of these phenomena, which are to be discussed by themselves, and which are of such special interest that no general statement concerning them would be at all satisfactory. We will, therefore, hastily review the country southward and eastward to Camp Brown, the closing point of our labors.

South of Yellowstone Lake, although the volcanic rocks still continue, there are numerous places in which the sedimentary strata are revealed beneath them, or are uncovered by them. These occur mostly on the banks of streams which are tributary to the Snake River. On Lava Creek the granites are exposed, overlaid by a quartzose sandstone, which is probably Potsdam, and this by limestones, which may be of the ages of the Quebec group and the Niagara limestone. Cretaceous strata are exposed before reaching Lava Creek on our route; also the coal-bearing series on Buffalo Fork. The strata containing the coal are nearly vertical and in folds, so that the beds are several times exposed along the cañon within a stort distance. Much of this coal is very good, and will, doubtless, some day be of value. Drift is very abundant in some places between Two-Ocean Pass and Tógwote Pass. Near the latter point, the eruptive rocks are largely denuded, if they ever covered the lower strata, and the sedimentary rocks are finely cut through diagonally by the Wind River, exposing numerous good sections. Before reaching North Fork, this river has passed through the later formations, and is then almost entirely walled by the Tertiary beds for the remainder of its course. The drift-accumulations are very abundant, both as bowlders and gravels and as modified drift. The details of its distribution are in many respects very similar to the synchronous deposits of the Green River Basin. It would seem that the Pliocene beds, if any were formed in the Wind River Basin, were quite local in extent, but the evidence of action during the Champlain epoch is much more conclusive. Well-formed terraces mark the courses of the streams here as elsewhere, and recent surface-deposits are, perhaps, as well shown as anywhere over our district.

ECONOMIC GEOLOGY.

It has not been the main purpose of the writer to collect statistical information, nor to examine the country with special reference to its capabilities for improvement, but such data have not been entirely neglected, and the following summary of facts in this connection will not be without some interest to a large class of people.

The Sweetwater gold-mines have certainly not been worked to their full capacity, and the introduction of capital and machinery consequent upon the increase of railroad facilities, which must no doubt take place at an early day, will probably add to their productiveness. In such an event, markets will be produced for the garden-truck which can be very readily raised in many parts of the Wind River Valley, where the facilities for irrigation are of the best. The deposits of coal and oil can doubtless then be utilized; the inexhaustible store of building-material, of stone, and the abundant supply of timber will furnish ample accommodations for the settlers, as it has already done at Atlantic City, South Pass City, Miners' Delight, Camp Stambaugh, and Camp Brown. The gypsum-deposits will be found valuable and easily obtainable, while at no very great distance iron-ore may be cheaply worked. The main railroad through this country will probably be on the regular route to the National Park from the East, and distant markets could be supplied with the products of this section. The Potsdam sandstone, it is very possible, is in some parts well calculated to be used in the manufacture of glass, and a good quality of lime can be produced from much of the limestone.

Everything considered, the Wind River Valley is the most favorable locality for this development, but it can be extended across the Owl Creek Mountains to the Shoshone plateau and beyond without difficulty. The rich fuel-deposits along the line of the Union Pacific Railroad will some day demand the introduction of an agricultural population to furnish the food-supply. Very many localities are now very favorable for grazing purposes, and the soil is, as a rule, very rich in the necessary ingredients of plant-food. In most places irrigation is all that is needed to turn the desert wastes into productive fields, as has been done in the Salt Lake Basin, and on the Rio Virgin, by Mormons. The possibility of irrigation is a deeper question, but it is certain that much can be done in this direction even now, while the capabilities of the future will very largely depend upon the measures which are adopted to husband and distribute the water-supply. There are those, and the author is one, who believe that the results to be obtained in this way will be almost exactly commensurate with the time and money which may be spent in diligently working out the problem of the influences of vegetation upon atmospheric precipitation. This is not the place for argument upon this subject, and this reference to it is all that can here be made. Enough has been said, however, to show that the possibilities of advancement are far greater than many have imagined, and it will be found that these views are shared in common with the great majority of observers in this region, who are competent to form an opinion from the facts.

CHAPTER VII.

DYNAMICAL GEOLOGY—ELEVATION, EROSION, AND DENUDATION.

Mountain Elevation—Erosion and Denudation—Glacial Action—Aqueous Action—Peculiar Effects of Erosion—Wind Action.

In all the preceding chapters we have dealt mainly with results, studying the history of each epoch from its completed works, and paying but little attention to the forces which have aided in their production. In Chapter II, when reviewing the general surface-features of the country, it was stated that there are many physical peculiarities which are at first sight remarkable, and which must be, in a measure, explained, before one can fully appreciate the great changes which have taken place in this portion of the Rocky Mountain region since the formation of the earliest strata. This portion of the report is, therefore, devoted to a consideration of the causes of these changes, with a more complete account than has previously been given of the direct effects; that is to say, the indirect, or ultimate effects, will require little notice, as they have already been discussed in the chapters on stratigraphy. In other words, we are now to deal, in a general way, with forces which have been at work more or less permanently, and we shall endeavor to trace their action in the production of results, many of which have been already considered. The subject will be topically discussed, somewhat systematically, but with scarcely any regard to local or chronological sequence, except in the treatment of minor or special topics.

ELEVATION OF MOUNTAINS.

It has been elsewhere remarked that the elevation of the Wahsatch and Uintah ranges was accomplished before the chain of the Rocky Mountains eastward had risen to any extent above the ocean. This conclusion was reached by Clarence King, from the fact that the Cretaceous beds extend up to the eastern base of the Wahsatch chain, but they are not found upon the western slope. The relation of the Cretaceous strata to the underlying rocks in the neighborhood of the Wahsatch and Uintah ranges also favors this belief. Previous to the deposition of the Paleozoic strata, an uplift of limited extent occurred in Arizona, according to the published reports, and some statements have been made in Chapter III of this report, which point toward the conclusion that there may have been a slight elevation somewhere in the neighborhood of South Pass during early Paleozoic times. This latter supposition requires further evidence, however, for its support. The Wahsatch and Uintah ranges, then, were uplifted toward the close of the Jurassic period, with a broad area westward, the whole of which was thrown into a series of parallel folds, with a general north-south trend.

The upheaval of the ranges composing the Rocky Mountain chain, east of the Wahsatch range, took place at a later date. The disturbance appears to have commenced during some portion of the Cretaceous period, and to have continued gradually until its close. King also reports a later uplift affecting Green River Tertiary beds in the neighborhood of the Wahsatch Mountains. It is very difficult to determine the complete orographic history of the northwestern portion of our district, but the uplift of the whole region seems to have been completed before the opening of the Miocene epoch, although large additions have since been made to its height by the accumulation of material poured out over its surface.

The Jurassic upheaval, as well as that of the Cretaceous period, was accompanied by sufficient heat to transform or metamorphose a great thickness of strata below the Potsdam sandstone, and almost to melt some of the lower beds, if the granites be rightly considered a part of the metamorphic series. North and west of the Wind River Mountains, the heat accompanying the later upheaval was so intense as to lead to outflows of igneous material from fissures, upon a scale of such magnitude that whole ranges were concealed and a new aspect was given to a vast extent of territory. These ejections of molten matter continued with greater or less force during the Miocene epoch, and probably through the Pliocene, or even later, gradually diminishing in quantity until the fissures were covered by lines of volcanoes, from the craters of which the lava poured down upon all sides at irregular intervals. The remnants of many of the cones now stand as clustered peaks, to mark their former positions. These volcanoes finally became extinct, and geysers, fumaroles, and solfataras, in almost inconceivable numbers, were left through succeeding ages to attest by the accumulation of enormous mineral deposits the persistency of the subterranean heat. Many of these still remain, but they are slowly dying out, and it is evident that they represent the last stages of the volcanic action.

The development of the eruptive rocks is very great westward, and the author would here express his obligations to those investigators whose writings have enabled him to obtain additional evidence of the truth of several opinions which were formed in the field, and largely confirmed by the study of notes and specimens. In the succeeding pages these views will be freely expressed, together with the facts upon which they are based.

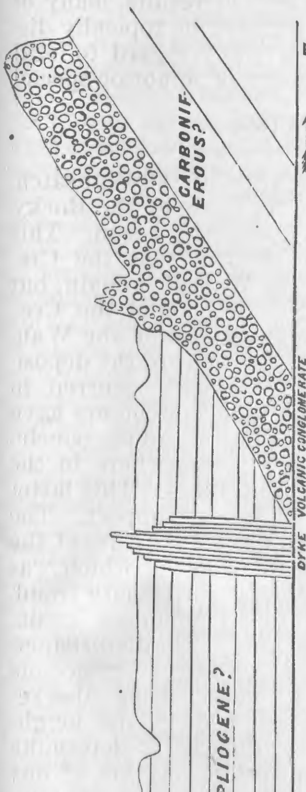

FIG. 14.—Section partly ideal, showing relative position of lower volcanic conglomerate on North Fork of Stinkingwater River, between Camps 32 and 33.

In the lower portion of the cañon of the North Fork of Stinking Water River there occurs a peculiar patch of Tertiary rocks, lying nearly horizontal upon each side of an almost vertical dike of compact andesite, in such a manner as to leave no room for doubt that some of the volcanic rocks were deposited prior to the existence of the fresh-water Tertiary lake in which the horizontal beds were formed. These strata are composed of about 300 feet of clays and light-buff sandstones, very similar to the Pliocene beds in the neighborhood of South Pass. It was impossible to determine whether this basin was continuous with an outside lake during the deposition of these strata, but it appears to have been quite isolated, and not more than a dozen square miles in area. Figure 14 illustrates the section referred to. Similar Tertiary beds, with nearly the same relation to the lower volcanic conglomerate, also occur near the junction of the Owl Creek Mountains and the Sierra Shoshone, at a much higher level than these.

Beyond this point the dikes are very numerous, but usually rather narrow, at first cut through by the stream with a general north-south trend parallelwise to the axes of the folds in the underlying sedimentary rocks, then becoming more abundant and irregular and crossing each other in almost every direction. Figure 15 gives an outlineview of several dikes, as seen in a cliff on the right bank of the sream, a short distance below Camp 34.

The conglomerate frequently contains large masses of the sedimentary rocks, particularly those of Tertiary age, which are often baked so hard as to give a peculiar metallic ring when struck with the hammer. In these not unfrequently finely-preserved specimens of leaves of angiosperms are found, almost indelibly impressed upon the rock, much after the manner of the porcelain print. Logs, stumps, and even trees silicified are found in many places in large quantities.

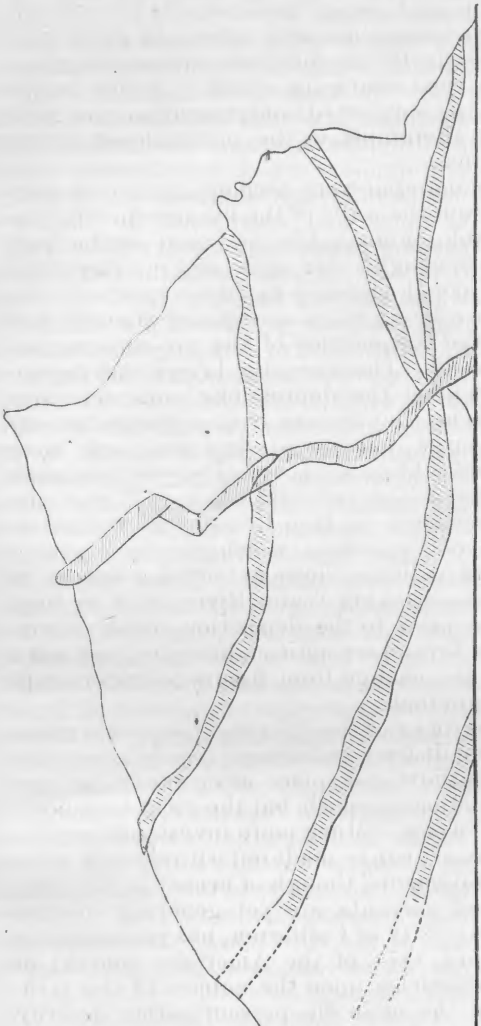

FIG. 15. Andesite? dikes in breccia-conglomerate, in cañon of North Fork of Stinkingwater River.

The effects produced upon the sedimentary beds by the outpouring of the heated volcanic material upon them are very instructive. Hard limestones have become friable, sandstones have been changed to the texture of quartzite, and beds of gypsum have been very much hardened where they have not been converted completely into anhydrite. Some beds of cherty limestone have also been rendered even more compact and finely-jointed, and apparently some beds of sandy marl have been locally transformed into quite compact but much-jointed rock.

As we pass up the cañon of North Fork the conglomerates are interstratified with and overlaid by thick beds of trachytic material varying in texture and inclosing many minerals. The whole series to the Stinkingwater Pass is of great interest, but few lithological details can herebe given.

Judging from all the facts which have thus far been gathered, we may read the history of these deposits in this region, including as well their continuation beyond the limits of our reconnaissance, briefly as follows: During the Cretaceous period there began a disturbance in the strata east of the mountains which had been elevated at the close of the Jurassic period, resulting in the upheaval of the Rocky Mountain chain. This was gradual in its effects, and, whatever may have been its cause, the trend of the new system was parallelwise to the axis of the previously-formed chains; in some portions of its length the later system is almost exactly parallel in trend with its predecessors. Over a large part of the area now occupied by the Sierra Shoshone a considerable range was probably elevated during the period of the Cretaceous upheaval. This is now so nearly obscured by the igneous deposits that the evidence of its age is difficult to obtain, and it is at best very fragmentary. In some respects it resembles more closely the Jurassic than the Cretaceous mountain-chains, but wherever the Cretaceous beds are exposed in the vicinity of its ridges they are invariably involved in the folds; it must, therefore, be considered a portion of the Rocky Mountain system. From a review of all the facts which bear upon this subject it is inferred that the nucleus of this concealed range is to be found in a belt of granites and other metamorphic rocks extending northward from Tógwote Pass, bearing about 19° to the west, and crossing the East Fork of Yellowstone River just above its mouth. If this be the case, the range formed a part of the northward continuation of the main geological divide of the Rocky Mountains, or the prolongation of the axis of the Wind River Mountains.

The early outflows of igneous material were accompanied by masses of the stratified rocks, broken from the walls of the fissures no doubt in many cases, but also, it is probable, entangled in the liquid stream from the upturned edges of tilted beds, caught from cliffs, and in other ways accumulated until thick beds of conglomerate had been deposited. As a rule, the successive outflows are arranged in a stratified manner, and the lower layers follow closely the inequalities of the pre-existing surface, wherever the latter is exposed. The overlying layers, and especially the lavas, have gradually filled the depressions until the later outflows have passed away from the fissures over a comparatively even course. In some places large patches of stratified rock have apparently been engulfed in the lava-flows without removal from their position; and there may be seen in the left wall of the cañon of the Yellowstone, not far above the mouth of Hell-Roaring River, and at other points, the upright trunks of large trees, which may have grown where they stand. None but the earlier outflows extended eastward to the mouth of the North Fork of the Stinking Water River, or, if so, they were removed from a broad area prior to the deposition of the provisional Pliocene beds. No sudden breaks are noticed, however, westward to the Stinkingwater Pass, but the change from fissure to crater eruption seems to have been rather gradual.

It is possible that the eruptive rocks of the Jurassic upheaval extend eastward beneath a portion of the district under consideration, but this is rather doubtful. A limited outflow took place after the Cretaceous period, and perhaps prior to the Miocene epoch, but the great lava-flows probably occurred during the Miocene. Much more investigation is required before the details of this history can be made out with certainty, but it is believed that the foregoing statements, though of necessity less complete than the material collected warrants, are yet generally correct. Prof. Joseph Leconte, of the University of California, has published, in the numbers for March and April, 1874, of the American Journal of Science and Arts, two admirable articles upon the subject of the lava-floods, with whose conclusions in the main the present author heartily concurs—the chief differences in the facts being due almost entirely to local causes, independently of age. It would be a pleasant task to follow this subject to the end, but the peculiar difficulties under which this report is prepared forbid further discussion, and it is very reluctantly dropped at this point.

The Owl Creek range is a kind of spur or shoot from the angle formed by the bending eastward of the main axis of the Cretaceous upheaval, and, with the many folds of similar date, doubtless served as the mechanical expression of much of the elevating force which would otherwise have been converted into heat for the melting of the rocks.

ANCIENT EROSION AND DENUDATION.

Perhaps the greatest difficulty in the way of generalizing correctly upon the results of field-work is that of determining accurately even the main surface features of the country at any given period in the past. It is rare, indeed, that one will find each successive step in the history so clearly and unmistakably revealed that it may be read with ease in a hasty passage through a complicated district. There can be no doubt that erosion has been as active in past times as at present under like conditions. We must, therefore, believe that each succeeding formation has been built up from the waste of those which have preceded it, wherever the latter have been exposed to disintegrating influences. The evidences of excessive denudation of some portion of the earth's surface during the Paleozoic era are abundant, but there is no proof of the existence of extensive tracts of land high above the sea-level, in Western Wyoming, until the period of the Jurassic upheaval. The elevation of the Wahsatch and Uintah ranges, with the accompanying Sierra Nevada chain, then furnished ample material for the accumulation of the arenaceous and other deposits of the Cretaceous seas, and the succeeding estuaries and fresh-water lakes. Subsequently the uplifting of the Rocky Mountain chain added largely to the superaqueous surface, and, notwithstanding the conservative effects of the luxuriant vegetation during much of the Tertiary period, the country was denuded to an extent sufficient to produce at least three thousand feet of lake-sediment over a very wide area. It is safe to conclude that the average height of the mountains in this section was reduced by denudation fully one thousand feet during the Tertiary period alone, and if we add to this the accumulation at their base of more than three thousand feet in thickness, we shall have a reduction in altitude, from base to summit, of four thousand feet since the Cretaceous upheaval, without taking into account the denudation during the Glacial epoch. There are good reasons for believing that this estimate is much too small, for the Eocene beds of the Green River Basin present a thickness of certainly four thousand feet. Two thousand feet of beds which are probably Miocene occur in the Wind River Valley, and the Pliocene beds near South Pass are fully one thousand feet in thickness. It is almost impossible to decide how much of the material deposited in the Green River Basin was worn from either mountain system, but some clew to the proportionate amount furnished by the Wind River Mountains may be obtained by an examination of the physical features of that range. During the Eocene epoch there seems to have been a comparatively free passage for the waters upon the northeastern slope; and, although the erosion may have been as great as at a later period, very little of the material was deposited until it had passed some distance from the mountains. Upon the western slope a great lake existed during this epoch, and whatever fine material was carried down by the streams was deposited in the Green River Basin. In the Miocene epoch these conditions were almost reversed as far as the opposite sides of the range were concerned, and during the Pliocene epoch both shared in the deposition to some extent. Judging from the present aspect, and taking into consideration the effects of the glacial action, it seems very probable that the Wind River Mountains have always been characterized by greater erosion upon the northeastern slope, though it must be acknowledged that less is known of the southwestern flank.

In the Owl Creek range and the Sierra Shoshone almost nothing can be learned of the early denudation, but in both of these the drainage appears to have been mainly northward and eastward, as at present, though not in all cases through the same channels.

GLACIAL ACTION.

To one accustomed to the heavy drift-deposits of the East, often bearing evidence of transport for many miles, the local nature of the western accumulations, in view of the excessive erosion which has been produced in certain sections, is somewhat bewildering. It is unnecessary to repeat here the facts and explanations which have been offered in Chapter V, but an attempt will be made to give a more satisfactory review of some topics which were there too briefly considered.

It has been remarked that the general course of the glacier movement was southeastward, varying more or less according to the resistance encountered, and spreading out, in some cases, nearly at right angles from the sides. In the Wind River range the main glacier followed a course apparently not strictly parallel with the axis, but trending slightly more toward the east, so that the erosion was usually much greater upon the northeastern slope. From the top of the Chimney Rocks, in the axis of the range, the whole country northward and eastward can be taken in at a glance, but the view in the opposite direction is extremely limited, being almost entirely confined to the exposures of the metamorphic series.

There are many remarkable features in the erosion of channels which, from their form and the partial filling in of undoubted drift-deposits, no one would hesitate to refer to the Glacial epoch, but which it taxes the mind to trace to their special causes. The absence of grooves or striæ from sections in which the volcanic products are almost universal may be accounted for by the rapid weathering; but it is more difficult to understand why they should not be found in the harder and more durable metamorphic rocks. The only instance during our trip in which I was able to detect anything approaching to the nature of a glacial mark, was in the case of a very limited outcrop of a dolomitic limestone above the Niagara, which had upon its surface two or three faint scratches, which may have been quite recent.

In the valley of the East Fork of the Yellowstone, and on Lava Creek, a quantity of very large granitic bowlders are strewn over the surfaces of the higher terraces, and similar masses of granite occur isolated and in moraines, in the central portion of the Wind River range. In the latter, outside of the nucleus, large masses of the stratified rocks are occasionally seen standing by themselves, but usually in such positions as to indicate transportation very gradually, and for short distances only. The bowlders becoming smaller extend out into the plains, and some of them are composed of the material of the sedimentary rocks, sometimes containing fossils.

The general course of the glaciers over the igneous district was not very different, and all the observed peculiarities of the drift in this region are traceable rather to the outlines of the surface and the texture of the rocks than to any important difference in the glaciers from those farther south. In the upper valley of the main fork of Owl Creek there are extensive accumulations of bowlders running down from the east in low ridges, similar to those noticed in the Wind River Valley. The erosion was rather uneven, and the southern-bound glacier seems to have met an insurmountable obstacle in the Owl Creek range, and to have been deflected from its course; or, perhaps, the erosion was effected by separate glaciers existing at different times, and possibly pursuing different courses. At any rate, there is abundant evidence, also, of the final deposition of volcanic-drift material at the base of the mountains, between the upper and lower cañons of Owl Creek, far to the eastward. Mere glimpses were obtained of the wonderful history which is yet to be unraveled in this region, but enough was learned to show that these deposits and their channels are but the subordinate parts of one system, in unison with similar accumulations in other portions of the district.

Between Pacific Creek and Lava Creek, and in the valleys of Lava Creek, Buffalo Fork, and Rock Creek a large portion of the drift is very finely comminuted, and this is often the case elsewhere in the volcanic district, especially where the lavas prevail. Many of the metamorphic bowlders may have come from the volcanic conglomerates. Much modified drift, probably of the Champlain epoch, occurs in the valleys of Buffalo Fork, Rock Creek, and in other places, of which the later terraces have been formed. In these cases, and perhaps in many others, there is evidence that a part, at least, of the valley was cut out by a glacier, and the same may be said of portions of the valleys of the majority of the streams in the Uintah and the Wind River ranges, as well. As before remarked, however, it is almost certain that the narrower cañons of many of the streams have been for the most part, or entirely, cut by running water, partly or wholly since the Glacial epoch. In some places the streams have plainly turned from their original courses to cut deep cañons through solid rock; at other points these cañons, though narrow, bear unmistakable evidence in the shape of drift-deposits that they were partly cut as early as the close of the Glacial epoch, while some even appear to have been in progress during the Tertiary period.

From the facts that have been given in this and a previous chapter, it cannot be doubted that, whether the movement were rapid and evanescent, or very slow and longer continued, the element of power was present, though it seems to have become concentrated in its effects, causing extensive erosion with little transportation, comparatively.

RECENT EROSION.

In discussing the causes of the erosion and denudation which have taken place since the close of the Post-Tertiary period, it is often impossible to separate that part of the effects which properly belongs to the Champlain or Terrace epoch, nor is this necessary for our present purpose. The term *recent* at the head of this division will, consequently, be used to designate all that time which has elapsed since the period of the drift.

AQUEOUS ACTION.

Since the laying down of the fresh-water Tertiary strata they have been denuded to a degree almost incredible to one who has never visited the region in which they occur. The Green River Basin in particular has been subjected to this process, lying as it does almost completely hemmed in by the mountains. The Bridger beds originally covered the Green River formation over the greater part of the basin with at least one thousand feet of clays and sandstones, but now the lower group is laid bare to a remarkable extent by the complete wearing away of the superincumbent strata. The position of the drift-deposits, at least in the southern portion of this tract, indicates that much of the denudation had been accomplished prior to the close of the Post-Tertiary period, and it is probable that local glacial action had much to do with the early erosion, though I have had no opportunities of observation of such effects, except in the vicinity of the Uintah Mountains and near South Pass, in both of which cases there is no doubt that extensive denudation was accomplished during the Glacial epoch. Of the great effects which have since been produced, the largest part must undoubtedly be attributed to the action of running water during the Terrace epoch, in comparison with which the amount is very small which has taken place in modern times. Nevertheless it must not be thought that the erosion now in progress is by any means of trifling importance. On the contrary, it would be a simple matter to bring forward abundant evidence to prove that the amount of the material which is annually removed by the streams is excessive when compared with ordinary standards. There are many causes of this, a few of the more important of which may here be mentioned.

1. *The great altitude of the region.*—Two prominent results accrue from this cause, viz, the accumulation of snow in the mountainous districts, and an increased force to the currents of the streams arising from the greater slope of the surface.

The accumulation of the greater portion of the atmospheric precipitation during a long winter causes powerful freshets in the late spring, which produce greater effects upon the surface than would be accomplished by the same amount of water passing off gradually. The mountain-slopes give free scope to the action of gravity, and the streams strike the plains with a force sufficient to carve out deep channels in the soft strata, and to remove large quantities of the finer material, as sediment, to great distances.

2. *The alternate melting and freezing of the snow by day and night.*—In this section of the country during the months of late spring and summer there is usually much difference in the temperature of the days and nights. The snow in the mountains thus melts by day and freezes by night, causing alternations in the level of the streams of considerable magnitude. In some instances these changes are so regular for days at a time as to closely simulate the ebb and flow of the tide in rivers communicating with the sea, except in the length of the intervals. The frequent importance of very slight differences of this nature, dynamically considered, will be readily acknowledged.

3. *The character of the rocks.*—This influences not only the amount but also the character of the erosion. Accordingly we find that the Bridger beds, where they have not been entirely removed by the long-continued action of the streams, are left standing for the most part as isolated hillocks, though these vary greatly in size and frequency. The harder Green River beds are usually more regularly and perpendicularly worn. Between the extremes nearly every possible form may be met, according to position, and other circumstances which are generally not difficult to understand. To this cause must be mainly attributed the irregularity in the results which have been produced, for the aqueous eroding agencies, though not constant in their intensity, have practically always held about the same relations to each other as at present.

These and other agents acting in concert are steadily degrading the surface by undermining the cliffs, washing out the alluvial deposits from the old stream-beds, and transporting the finer material to points below. One who has only seen these stream-beds in the late summer or early fall, when they are traversed by mere wiry rivulets, can form no adequate idea of the powerful river-torrents which fill and often overflow their banks for several weeks early in the season, so thoroughly charged with sediment as to appear more like mud than water.

The foregoing remarks will apply almost equally as well to the Wind River Valley and to other portions of the Rocky Mountain region where the conditions are similar, but there are usually minor differences, dependent upon a variety of circumstances which are more or less special in occurrence. The sandstones are at the surface over a large portion of the Wind River plateau, which has caused the erosion to result in valleys and gorges similar to those which have been cut through the beds of the Green River group. In some cases peculiar buttes of small size remain, and Crow Heart Butte and another similar to it, in the main valley of Wind River, are in some respects like the more regular ones of the Bridger group. There are also "bad lands," exposures of the indurated green and red marls of the Wind River Tertiary, near the mountains and in the upper valley where the upper sandstones have been worn away, having a peculiarly rugged aspect. These may very appropriately be named the Gothic Buttes. The peculiar mixed structure of some of the sandstone-conglomerates of this formation has given rise to many curious and remarkable forms resembling familiar objects, as urns, pillars, altars, &c., and many of the Grizzly Buttes near the Uintah Mountains are capped by masses even more strikingly similar in outline to other less regular objects. In the volcanic rocks the chasms are lined with caverns, pillars, towers, and steeples, often hundreds of feet in height. In some cases narrow fissures have been produced by water-action through lavas and conglomerates thousands of feet in depth, so that, in numerous places, the whole formation now has an extremely rugged, turreted, and castellated appearance. It seems remarkable that many of these thin chimney-columns can remain in position. In the cañon of North Fork of the Stinking Water, in one locality, there is a vertical block of volcanic material less than fifty feet in length, *two feet* in breadth, and five hundred feet in height, standing alone at a distance of three or four feet from the north wall of the cañon, and this is but one of many similar instances which might be given. Hundreds upon hundreds of lofty pinnacles, deep-worn caverns, and fathomless crevices attest the resistless power of apparently insignificant forces with unlimited time in which to work; they stand as mute witnesses of the almost inconceivable length of the era which has elapsed since the comparatively modern igneous ejections; and they add one more to the long list of proofs of the immensity of geologic time.

Sections taken at intervals across the valleys of the streams would show that the erosion, ancient and modern, has been very unequal at different points, and it may seem rather peculiar that this statement is nowhere more applicable than in the volcanic district. This is no doubt largely owing to the local nature of the glacial action, but it must be partly attributed to the character of the rocks and partly to other existing causes. In the lower part of the cañon of North Fork, hard dikes of trachyte are abundant, many of which are almost vertical. These rarely cross the path of the stream at a right angle to it; but, in most cases, being tougher than the adjacent rocks, they now jut above them, and in a line making a more or less acute angle with the stream. This causes much of the detritus from above to accumulate behind the high walls thus formed, affording lodgment for trees and other vegetation, and allowing of the growth of thickets of symmetrical pines on slopes so steep that there would otherwise be frequent land-slides. This is well shown by the comparative absence of growing timber from lesser slopes which are not thus protected.

Some of the most remarkable and interesting effects of water-erosion are to be seen in the Yellowstone Valley, where the gradual draining of the very large ancient lake has caused the formation of a river-channel of very great depth. The Great Falls, at a distance of fifteen miles below the lake, are a complete study of themselves. (See Fig. 16.) For a number of miles above the rapids the river runs through a broad, level, grassy bottom, made up of sandy lake-deposits and of gravelly deposits of the stream before the period of its present level. Here it pursues a very tortuous course, but the current is visibly rapid, although the water is too deep for fording, except in a few places. Below the mouth of Sour Creek the sandstones and fine beach-conglomerates, largely composed of volcanic material, are cut through by the stream, which is thus narrowed at first, and then turned slightly eastward. It next strikes against ridges or masses of purplish trachyte-porphyry, containing crystals of sanidine. This is made up of alternations of fairly compact and slaggy portions, the latter containing reddish-brown botryoidal geodes and spherulites. Much of the material is very nearly pearl-stone, between which and the trachyte-porphyry there is an almost insensible gradation. The resistance offered to the current by the hard face of the trachytic-porphyry creates a counter-current, which causes a bay-like expansion of the river, in which the water appears almost stagnant. No notice is given of the coming turmoil save the muffled roar from the rapids below. But the rock also feels the shock and it is finally cut through, this action being facilitated by the jointage of the rock. The stream now pursues a general course along one of the lines of jointing, trending north 4° west. It then meets the perlitic trachyte-porphyry, which, being thinly bedded and more loosely arranged, yields more readily to the eroding forces, making swells at the sides and transverse troughs or gullies in the bed of the stream, the action upon the sides being increased by the formation of eddies produced by the striking of the main current against another portion of the tougher or non-perlitic rocks. Here the rapids begin, but they are not yet very boisterous. At each ridge of the more massive material more or less of an eddy is formed by the resistance of the rock, which causes currents to rush in from the sides to join the main current in the center, thus throwing the eroding force by degrees toward one point, concentrating it, and enabling the stream to force its way through the remainder of the section in a straight and narrow gorge. The rapids or cascades are largely due to the irregular erosion along the bottom, as will be seen by examining its general outline represented in Figure 17.

The terraces bordering the river at this point show the same features, but they are much more regular at a distance from the stream, as they have there been cut through the soft sandstones which overlie the porphyry. Upon the right bank, at the gorge, there are low spots or basin-shaped holes which, before viewing the rapids, were almost inexplicable, but were made clear when considered as the positions of eddies in the former stream. A mass of the harder rock also marks the place of a small islet in the stream at a higher level, which then stood in the midst of the rapids.

Figure 18 gives the existing contour of the surface at this point. A similar sketch would, doubtless, properly represent the transverse outline of the present bed of the stream at the lower rapids in the midst of which now stand the islets shown at II, Figure 16.

Below the gorge the river widens, owing mainly to the absence of hard beds in one spot on the left bank, which may have once been at the mouth of a tributary stream. It continues its course, alternately cutting into the right and left bank, according to the nature of the rock. The stream below the rapids, at the last rock islet, is thrown mostly into a deep hole near the right bank; then meeting hard rock it is thrown across to the left bank against hard rock, which forces it to pass through another gorge by the formation of a powerful eddy. Through this the water rushes with remarkable force in a short series of rapids or cascades, then suddenly plunges by a sheer fall of 150 feet down into a large amphitheater in which the water spreads out shallowly, flowing over a comparatively smooth bottom with little current. The cause of the falls is the rather sudden change in the character of the rock to a fine-jointed argillo-trachyte-porphyry, which gives way more readily to the action of the water than the more massive rock above.

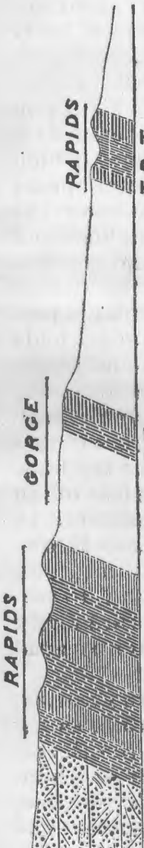

FIG. 17.—Ideal section along the bottom of Yellowstone River at the rapids above the Great Falls. The irregular surface line represents the bed of the stream. PPPPP, perlitic trachyte, (porphyritic.) TTTTT, trachyte-porphyry.

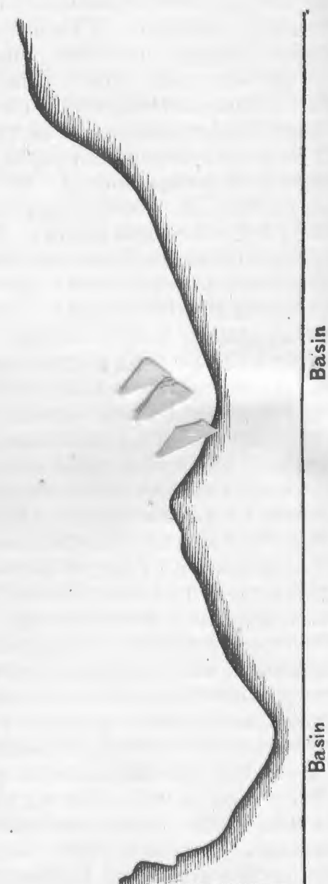

FIG. 18.—Basin-shaped holes in terraces upon the right bank of Yellowstone River at the gorge of the rapids above the Great Falls.

Less than a quarter of a mile below the upper falls, nearly opposite the entrance of Cascade Creek, the stream again meets with greater resistance, so that it is deflected very greatly from its course and narrowed at the same time. Just at the verge of the lower falls it is quite suddenly constricted by the protrusion of a hard ledge from the left wall of the gorge, which causes it to leap with redoubled energy over the steep but irregular precipice, (nearly 330 feet) which was undoubtedly caused by the passage to the softer conglomerates which here underlie the porphyries.

Numerous other intensely interesting studies of this character are available to the investigator in this wonderful region, but this one example must serve as the type of the class, and it will convey some idea of the enormous results of the long-continued action of running water, while it will also serve as another reminder of the great length of time which has elapsed since the geologically modern igneous products were deposited in this section. It must not be supposed that the transitions from one kind of rock-material to another are as abrupt in all cases as might, perhaps, be inferred from the foregoing description. On the contrary there are many varieties in the volcanic rocks alone. Between the rapids and a point in the Grand Cañon a few rods below the foot of the lower falls, I collected not less than twenty forms, exclusive of the sandstones and conglomerates, sufficiently distinct to merit special description. These include, besides those already mentioned, obsidian, obsidian-porphyry, various spring deposits, and other varieties which cannot be noticed here. These affect more or less the results of the erosion, but usually only in minor degree.

PECULIAR EFFECTS OF AQUEOUS EROSION.

From what has already been said of the present surface features of much of the country, it will not be matter of surprise to learn that there are many peculiarities in the manner of distribution of the atmospheric precipitation, and in other directions, which seem quite remarkable when portrayed upon any but the most minutely accurate maps constructed upon a very large scale, and even then they can be only imperfectly understood without at least a general knowledge of the geological structure. An examination of Captain Jones's admirable map will show the force of these remarks. One of the most striking features in the topography of the district is the interlocking or overlapping of the headwaters of many of the rivers, particularly in the portion occupied by the volcanic rocks. The continental watershed (see Figure 19) is now very irregular in trend north of South Pass, there being several instances in which the Atlantic waters rise far to the westward of the geological divide, and the Pacific streams *vice versa*. This result may be traced to two main causes, each of which has taken effect since the upheaval of Cretaceous date, *i. e.*, erosion or denudation and deposition. In some cases one of these causes has apparently operated to a much greater extent than the other. In the neighborhood of South Pass, it would seem that the deposition of the Pliocene beds has influenced the course of the headwaters of the Sweetwater River more than the previous extensive erosion, but it is an open question how much of the transfer of the precipitation from the western to the eastern slope through these channels is due to the subsequent glacial erosion. It is quite certain, however, that the latter has exerted a powerful influence, from the fact that the watershed at this place in most points is directly upon the Pliocene beds, which have been glacially eroded between the water-divide and the geological divide, or axis of the range, forming a trough in which the Sweetwater now lies, in part at least.

In the ancient volcanic district it is highly probable that deposition has had the greater share in the marking out of the present stream channels, though, as we have seen, these have been much enlarged and otherwise modified by the glacial action. The Yellowstone Lake Basin has undoubtedly been partly formed by erosion; but, as remarked by Doctor Hayden, the deposition of the igneous rocks around it has had much to do with its formation.*

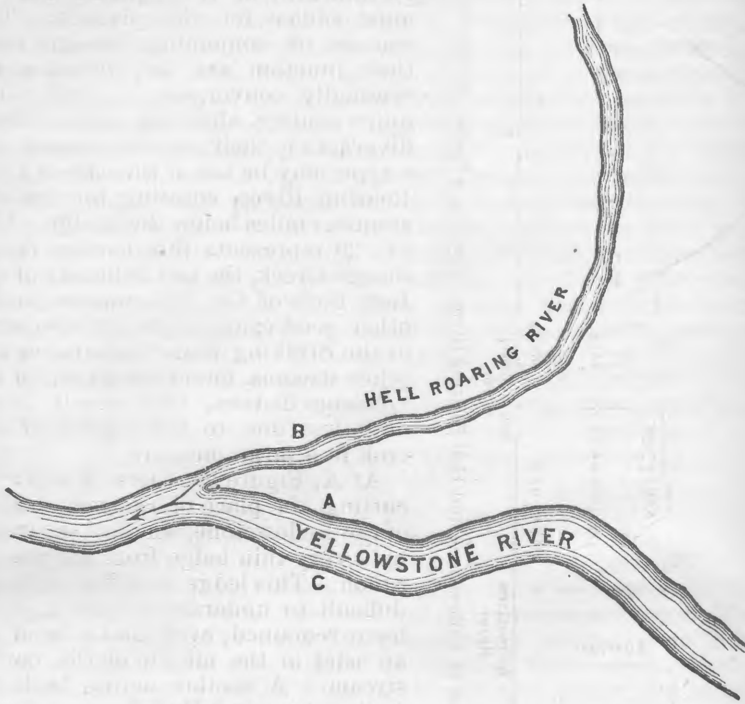

FIG. 20.—Example of acute junction of streams.

The occurrence of low divides in this portion of the Rocky Mountain region is somewhat characteristic. The slight elevation of portions of the water-shed at South Pass may be inferred from the fact that several of our party passed some rods beyond the divide before observing it, although they were at the time specially engaged in its determination. The divide at the Two-Ocean Pass, as the name indicates, is so nearly level that the single mountain-torrent which feeds the divergent streams is passed northward and southward with little disturbance, and an ordinary observer might pass from the Pacific to the Atlantic waters, or *vice versa*, without noticing for a time the difference in the direction of the currents. South of Yellowstone Lake the divide is often quite low, being, in places, scarcely three hundred feet above the lake-level, though some miles distant. Other examples have also been given in the course

* Doctor Hayden, in several places in his reports, has spoken of this basin as largely one of *elevation*. This term is liable to cause misapprehension, for certainly he cannot intend to express the opinion that the basin has been formed partly by its own elevation, but rather by the elevation of its boundaries by deposition. I shall therefore use the less objectionable phrase, *basin of circum-deposition*, which may be conveniently employed to designate such basins or valleys as have been more or less caused by the deposition of beds about them as an inclosing wall or walls.

of this report. In nearly all such cases these effects may readily be traced to the deposition of nearly horizontal beds in such a manner as to cover pre-existing ridges without materially affecting the general course of the drainage. This, at least, will explain the general results; but modifications of greater or less extent have arisen from subsequent erosion in special cases.

Among the many interesting features of this region one or two other peculiarities of the aqueous erosion must suffice for the present. The courses of conjoining streams near their junction are not unfrequently gradually convergent, so that they unite acutely, although often widely divergent in their general courses. As a type may be taken the case of Hell-Roaring River, entering the Yellowstone six miles below the bridge. Figure 20 represents this feature fairly. Slough Creek, the last tributary of the East Fork of the Yellowstone, is another good example, as are also some of the Stinking Water tributaries and other streams, found, as a rule, in the volcanic district, this result being doubtless due to the nature of the crok in a large measure.

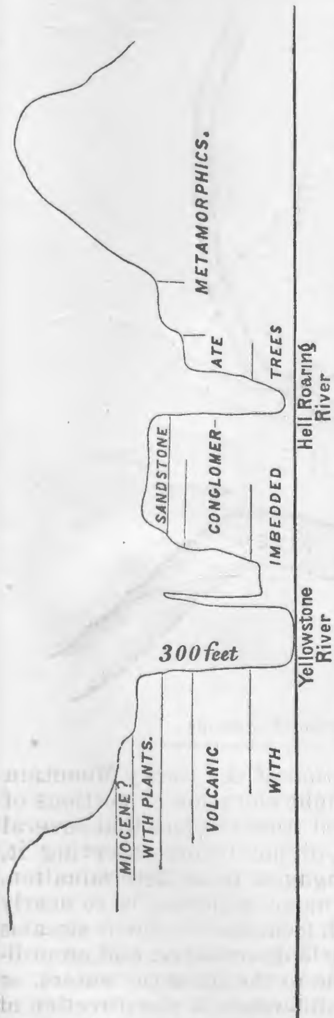

FIG. 21.—Section near junction of Yellowstone and Hell-Roaring Rivers, showing a former channel of the Yellowstone.

At A, Figure 20, there is a curious cutting, the place of a former channel of the Yellowstone, which is separated by a very thin ledge from the present cañon. This ledge is so frail that it is difficult to understand how it could have remained, even had it been but an islet in the middle of the earlier stream. A section across both the Yellowstone and Hell-Roaring Rivers is shown in Figure 21, including this thin wall.

WIND ACTION.

Like the circulation of the water upon the land, the atmospheric movements are also controlled by the topography of the country to a very great extent, and it will not be surprising to find that the results of such action, in a district composed of comparatively level plains, bounded by high walls upon one or more sides, have a certain uniformity about them which could not be expected in more open tracts.

The Green River Basin is, practically, a plain, hemmed in upon all sides but the east by snow-clad mountain-ridges, while the open side communicates with a wide expanse of prairie-surface. During the summer the heated air rises from the plains, causing a current which is kept up by the continued supply of colder air from the mountains. The direction of the wind, or of the surface-currents, will thus depend partly upon the position of the outlet, but even more upon the location of the surrounding mountain-walls. The prominent features, as exhibited in

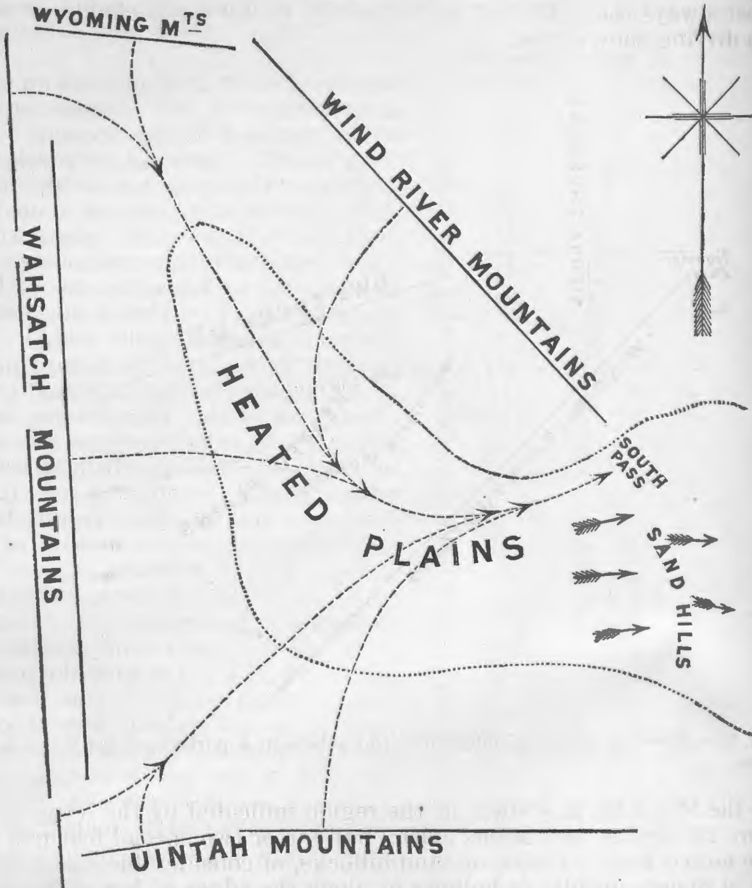

Fig. 22.—Showing cause and effect of wind action in the Green River Basin, Wyoming Territory.

the Green River Basin, are illustrated in Figure 22 and Figure 23 gives an outline view of the main facts as they occur in a portion of the Wind River Valley. The arrow points in both indicate the courses of the prevailing atmospheric currents. The power of the wind is plainly shown in the Green River Basin by the peculiar position of those composite plants which are collectively known as "sage-brush" and "grease-wood" in this section, and by the scooping out of the road-bed in some places to a depth of 3 or 4 feet. These plants, in spots which are well exposed to the wind, now stand upon isolated mounds or small hills, not unlike the potato plants in a well-tilled field, except that the hills are often three or four times the height of a potato hill. In the section marked "Sand Hills," in Figure 22, there is now a very large barren tract extending for miles to the eastward, said to be the abode of innumerable rattle-snakes, but it is entirely destitute of vegetation. When viewed in the reflected light from the sun it closely resembles an immense tract of drifted snow; and if a strong wind be blowing at the same time, as is almost always the case, one could readily mistake the clouds of sand for a driving snow-storm.

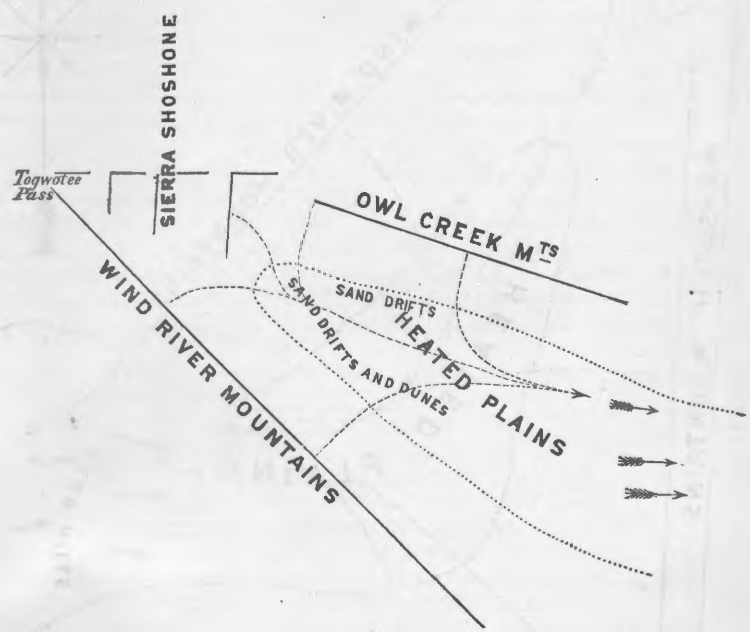

FIG. 23.—Showing cause and effect of wind action in a portion of the Wind River Plateau.

In the Wind River Valley, in the region indicated by the lettering in Figure 23, similar formations exist; but one or two special features deserve notice here. *Dunes*, or sand-hillocks, of considerable size may be seen in places, usually in hollows or along the edges of low cliffs which serve to break the force of the wind and cause the sand to be there deposited. Figure 24 represents the structure of the sand-drifts when only herbaceous vegetation is present. Here the prevailing winds are from the west, or nearly so, and the slope of the hillocks is much less upon that side. As a rule they are less regular than here represented, owing to the growth of clumps of grass upon many of the summits, which finally changes the hillocks into tufty hummocks.

Some peculiar forms of soft sandstone, already referred to as results of aqueous erosion, have no doubt received their finishing touches by the direct influence of the wind or by the abrading action of wind-blown sand. Many of the pinnacles and other irregular masses of rock which cap the conical and pyramidal buttes of the Bridger group in the Green River Basin, as well as the grotesque forms found elsewhere, were probably shaped in part by this force.

Lastly, the action of the winds in the felling of timber in large quantities has produced results the importance of which can scarcely be estimated. To say nothing of the ultimate effects which may be supposed to follow from the decay of the vegetable tissue and the possible or probable accumulation of peat, coal, or other material, there can be no question that the present features of a vast expanse of country in the West are due, in a measure, to the influence of these wind-falls upon the circulation of the water in the streams. The snow which becomes lodged in the intricate masses of logs resists the thawing power of the sun's rays for a longer time, and it is also often prevented from sliding down declivities with force. Streams are not seldom dammed or otherwise obstructed, retarding their progress for a time, only to renew their courses with increased power when the resulting lake overflows the barrier. Swamps are formed in other places, allowing of the growth of denser and more luxuriant vegetation, and the consequent increase of humus by decay. In these and in numerous other ways these all but impenetrable stretches of fallen timber are playing their part in the dynamics of the country, but chiefly by retarding the passage of the atmospheric precipitation from the mountainous districts and providing for its more equable distribution throughout the year.

FIG. 24.—Section across a sand-drift patch, Wind River Valley, north of Camp 24.

CHAPTER VIII.

DYNAMICAL GEOLOGY—CONTINUED.

Biological and chemical action—Effects of plant and animal life—Weathering of rocks—Chemical changes and products—"Alkali" deposits—Conclusion.

The geological action of plant and animal life, directly and indirectly, is, perhaps, too frequently overlooked in estimating the effects of the various forces engaged in the formation, destruction, and conservation of deposits, although it must be acknowledged that results of importance are often produced by these agents in their growth and decay. There are many questions of the greatest economic interest as yet unsettled which can only be finally solved by the accumulation of facts bearing upon this and kindred subjects. As a single example may be mentioned the opinion now quite commonly, but probably erroneously, held that forests exert an attractive influence upon the moisture contained in the clouds, but there are other subjects concerning which even less is known, which are more or less connected with the dynamical action of life.

In view of all this, a portion of the present chapter is devoted to a consideration of some of the important effects visible in Western Wyoming, which have been accomplished through the agency of living forms.

EFFECTS OF PLANT LIFE.

The geological results of the growth and decomposition of the members of the vegetable kingdom may be conveniently divided into three classes, viz: 1. Protective or conservative; 2. Formative, or reproductive; 3. Destructive.

I.—CONSERVATIVE ACTION.

In cases in which two or more forces are simultaneously at work in nature, it is often not easy to determine accurately the results which should properly be accredited to each, and even when certain of these agencies are antagonistic, the difficulty is not always decreased. Thus, the sand-hills southeast of South Pass, mentioned in the preceding chapter, (see Figure 22,) were there formed because of the absence of vegetation from that tract, but the lack of vegetation is, doubtless, caused by the power of the wind which has drifted the sand. The protective or conservative effects of plant-life, in the shape of the hardy "sage," and "grease-wood," are well shown in the *hillocky* region to the westward. So, also, in the sand-drift region of the Wind River Valley, before mentioned, (Chap. VII, Figures 23 and 24,) the growth of grasses upon some of the small hillocks has produced similar but less regular features upon a reduced scale. Figure 25 represents a section across the old emigrant-road and overland stage-route, at a point where its course lies in the direction of the prevailing winds. It will be seen that the sand has been blown out of the track, (which has been much worn by use,) to a depth of several feet, while the plants have protected the greater portion of the district, partly by their roots and partly by the resistance offered by their trunks to the wind.

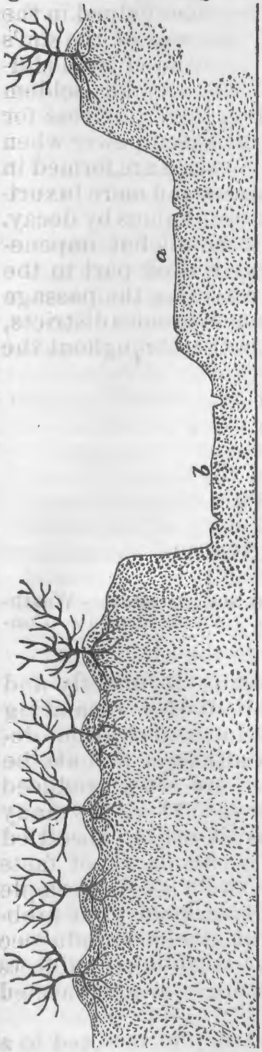

FIG. 25.—To illustrate the conservative action of "sage-brush" and "grease-wood," near Dry Sandy Creek, Green River Basin. *a.*—Newer road-bed. *b.*—Old road-bed. Both in use.

The influence of turf in preserving the surface of the land is well shown in portions of the Yellowstone Basin. A small stream which flows into Pelican Creek a mile and a half above the crossing of our trail illustrates this in a peculiar and remarkable manner. The amount of water which passes through the channel is not very small, but the matted turf layer of considerable thickness has held the stream within narrow bounds, thus preventing great lateral spread at the surface. Were the supply of water uniform at all times the undermining of the banks which is continually taking place might prove more destructive, but the difference in the amounts furnished during the spring and the summer is so great that the channel is overflowed in the flood-seasons, resulting in the production of shallow ponds. Occasionally masses of the overhanging turf (see Figure 26) fall down, damming the stream, and thus in a measure retarding the eroding action behind. In the upper portion the valley is very boggy, and here again the growth of the grasses prevents the soil from being removed, though a treacherous quagmire is the result.

The growth of underwood in numerous places has served to retard the transportation of material to the great advantage of many parts of the country. Accumulation of leaves, detritus, and other loose deposits are swept down in times of freshets in large quantities and retained, thus gradually increasing the depth of the river-channels by thickening the deposits upon the banks. The dense growth of gooseberry-bushes

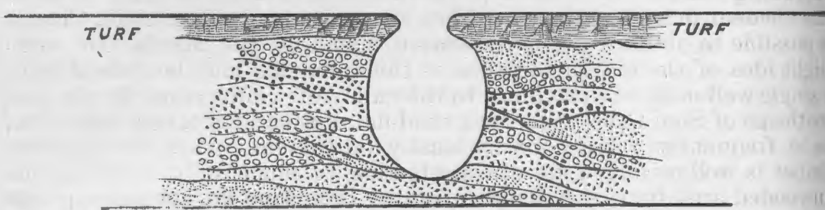

FIG. 26.—Average section across Fool Creek, Yellowstone Basin.

upon the banks, and almost in the bed of the stream of Gooseberry Creek, (tributary of Big Horn River south of Gray Bull River,) as well as the large patches of tall grass, resembling grain-fields, in the same section, are of the greatest value in this way, as is evinced by the less effective action of the stream in wearing away its banks, and by the more extensive accumulation of alluvium in these localities than at other points along the same stream. These and other plants of like nature are frequently met in similar situations, but they are especially characteristic of the volcanic district and of the region about the eastern base of the Sierra Shoshone. The excessive erosion of the Tertiary plains is attributable in a large degree to the general absence of protective vegetation, particularly to its absence from the vicinity of the streams. Numerous examples are in mind, which could be given, of the existence of deep gullies, small "earth-pillars" and other results of water-erosion which would have been almost wholly prevented had there been but a mere covering of turf or other matted vegetation.

Cotton-wood and other forms of *Populus* serve in the same manner as the willow, the gooseberry, &c., to bind the soil by their roots and prevent rapid waste of the land by running water. Fair-sized trees of this genus border the streams in favorable localities, not unfrequently accompanied by a dense undergrowth of the same plant, as upon the Middle Fork of Owl Creek, half a mile above Camp 26, where their value as a restraint upon the action of the water is well indicated by the depth and narrowness of the channel as compared with its limits beyond the extent of their influence.

The importance of accumulations of fallen timber in preventing the sliding and the rapid melting of the snow was mentioned in the last chapter. Growing trees to a certain extent answer the same purposes, and they also protect the surface in other ways. Binding the soil by their roots, even with added weight, they have been the means of retaining much of the detritus upon the steep slopes of the cañon-walls of the North Fork of the Stinking Water, and elsewhere, perhaps nowhere more noticeably than in the Grand Cañon of the Yellowstone. In the nucleus of the Wind River Mountains, huge bowlders have been imprisoned by the gnarled and tangled roots of the pines on slopes so nearly vertical that the snow could not rest upon them were it not for their roughness. The decay of leaves and trunks has covered the rocks in very many places so deeply with vegetable mold that the ordinary processes of weathering have been retarded or almost wholly checked. The ancient spring deposits on Gardiner's River and at other localities are extremely liable to degradation by erosion and decomposition, and yet they have often been remarkably well preserved, owing mainly to the protective action of plant-life and its results.

Lastly may be mentioned the protection afforded the less hardy plants by belts or patches of timber lying upon the side from which come the prevailing winds. It is always difficult to estimate the true value of this element in special cases without more extended observation than it is possible to obtain in a single season spent on the march, but some slight idea of the real importance of this influence may be gained from a single well-marked example. In the valley of Yellowstone River, just southeast of Sour Creek, there is a sand-flat of several acres so exposed as to be frequently acted upon by local wind-currents, while the adjacent timber is well arranged for the protection of much of the contiguous unwooded area from the same currents. The sand-flat is more or less covered with drifts and shifting dunes, but the protected portions are clothed with excellent grass. Similar features are noticeable, with variations according to circumstances, above the forks of Warm Spring Creek and in one or two other sections.

II.—FORMATIVE ACTION.

Allusion has already been made to certain accumulations of vegetable mold or humus, resulting from the decay of leaves and the trunks of fallen trees. There is nothing very peculiar in these formations, except that they are often rather remarkable for their extent and protective power. The thick layer of this material which now covers deeply the ancient hot-spring deposits of Gardiner's River is particularly noticeable on this account. This and other extensive accumulations in the present thickly-wooded districts bear abundant evidence of the coniferous nature of the vegetation, which, as now, has occupied these regions almost exclusively for centuries past. The dry pine "needles" falling upon the ground not only directly tend to increase the deposits, but they also largely prevent water-erosion of their own accumulations by the formation of a kind of thatch which protects the surface and serves to bind the decayed material more firmly together. These facts will probably explain the more abundant humic deposits in pine-clad countries, a feature not confined to the Rocky Mountain region.

Upon the treeless plains, when clothed with turf, the amount of the vegetable mold varies greatly, in some places being but two or three inches in thickness, while in others, more accessible to moisture and less exposed to the winds, accumulations of as many feet in depth have been formed. On the arid Tertiary areas remote from the mountains and away from the streams, especially in districts open to high prevalent winds, there is, practically, no formation of humus, although the soil is usually very fertile.

Many interesting observations concerning other deposits of this character are necessarily omitted here, though often extensive and of great importance. Alluvial deposits in portions of the district have been caused by the damming up of the streams by fallen timber or by drift-wood, but much more frequently by the retaining action of growing vegetation in the flood seasons. These latter accumulations are most abundant, perhaps, in the valley of the Upper Yellowstone River, though they are represented in parts of the Wind River Valley, and, markedly, on the tributaries of the Big Horn River north of the Owl Creek range, as well as in the valley of Burns' Fork, (Uintah Mountains,) and more especially on some of its affluents. Small lakes and ponds abound in many sections, and it would require a lengthy chapter for the description of the characteristic deposits of each, to say nothing of other striking peculiarities. To allude to some of these in a very general manner, it will answer the present purpose to divide these minor bodies of water into three not well-defined classes. In the first division may be included those lakes and ponds, with outlets, which are constant or perpetual, *i. e.*, those which retain water throughout the year, however they may fluctuate in level at different seasons. Such basins rarely receive important deposits of purely vegetable matter, except as driftwood, which occasionally accumulates to a certain extent upon the shores. Leaves and herbaceous stems will, however, become mixed with the alluvium, and thus aid in some slight degree in the formative process, though the comparative absence of deciduous trees from this region prevents such effects to any considerable extent. Another class of lakes, those, with or without outlets, which become dry during a part of the year by drainage or evaporation, may be the cause of not unimportant vegetable-deposits. A single case in point must suffice for illustration, although many might be given from notes taken in the field. About four miles south of Camp Brown, upon our outward march, on the first day of July, we encountered, directly in the road, a still pond of shallow water less than half an acre in extent. Around it, upon all sides, the land surface was exposed to the wind, and consequently mostly barren. Upon our return, in the middle of September, we rode through a slight hollow where the pond had been, now completely dry and clothed with the choicest grass, which was being made into excellent hay for use at the post. The soil in which it grew was quite rich in humus, the result of the decay of many previous crops not reaped by the hand of man. The third division embraces the stagnant pools and ponds of various sizes which are so very abundant in the Yellowstone Basin, though by no means strictly confined to that region. These are usually productive of important cumulative results on account of the continual progress of decomposition, which furnishes abundant food for the growth of many plants. Accordingly we find these places crowded with aquatic forms of vegetation, which by subsequent decay gives rise to noticeable deposits of humus.

Nor is this all. The very large tracts of country covered by fallen timber have so influenced the drainage as to form vast swamps in which the greater portion of the local vegetable products are retained and decomposed. In such places the vegetation is, of course, very luxuriant and of rapid growth, and it is also of such a character that the annual contribution of waste material, such as leaves, stems, and fruits, is much larger than in the drier and more exposed localities. The consequent accumulations of muck are very great, while to all this must be added the enhanced decay of the fallen timber itself, resulting from exposure to conditions brought about by its own prostration, though in many cases this is retarded by the antiseptic properties of the swamp extract, which only serves to increase the bulk of the deposit, however.*

In this connection, the enormous quantity of silicified wood, which is so commonly distributed in portions of the volcanic series, and which is now being formed to some extent by geyser action, may be mentioned in passing as one very prominent example of a vegetable accumulation. In this case, however, the result is due mainly to the exertion of forces elsewhere considered, and to the deposition of preservative material not derived from the vegetable kingdom. The process by which this

* It should be noted that the dryness of the climate and the nature of the vegetation together exert a retarding influence upon the decay of the blasted timber, thus adding greatly to the continuance of the above effects.

deposit has been produced will receive attention in a succeeding chapter, to which the reader is referred for further information upon this subject. To avoid repetition one or two other formations of minor importance, resulting more or less directly from the growth and decay of plants, but also dependent upon the action of geysers or hot springs, will be left for discussion beyond.

III.—DESTRUCTIVE ACTION.

So far as Western Wyoming is concerned it does not appear that the destructive effects of plant-life have been at all commensurate with the protective and reproductive influence of vegetation. Land-slides in the mountainous districts are very rare, if we may judge from the absence of frequent proof of such occurrences. There are many places along the walls of the cañon of North Fork of Stinkingwater River, where the loose earth and gravel is almost constantly falling down the steeper slopes, but this bears no resemblance in extent or effect to a real land-slide. Even upon the nearly vertical walls of the Grand Cañon of the Yellowstone, where pines often grow, there is no evidence of frequent or extensive changes of this nature. There is, on the contrary, conclusive proof that the roots of the trees often prevent land-slides by binding the soil and the rocks more firmly together.

The destructive element in connection with vegetation is, therefore, reduced to a small amount. The extensive growth of lichens upon the rocks, giving them at a little distance an unnatural color, shows that the disintegration due to their presence is notable, at least, although it would be difficult to determine the extent of their influence. Large trees, undermined by the wear of the water upon the banks of streams, cause considerable destruction when they fall by tearing up the soil about their roots, and the effect is produced more generally by the prostration of timber by the wind.

EFFECTS OF ANIMAL LIFE.

The geological or dynamical action resulting from the life and death of animals will be treated under three heads, similar in scope to the preceding, viz: 1. Protective effects; 2. Cumulative effects; 3. Destructive effects.

I.—PROTECTIVE EFFECTS.

Animals exert but little conservative influence in any way, and that indirectly, but it is, nevertheless, true that some slight preservation of the surface can be traced to them in this region. To say nothing of the hard-beaten paths or trails made by the domesticated animals of the white man and the Indians, game-trails almost without number are to be seen all over the district wherever the country is not so open as to allow of the scattering of the animals to feed, and one soon learns to detect the character of the animals which have made them, from certain peculiarities in each case. The bison prefers the plains, and the great weight of his body and its clumsiness compels him to climb the heights and knolls by a gradual or zigzag course. The elk often passes high up in the mountains, and the trails made by droves of this animal are quite direct, but never as steep as the courses often taken by the big-horn, or mountain-sheep. At first the passage of large droves of animals over the same course wears the surface, loosening it and causing the dust to be swept out of the trail by the wind, but the final result is to leave the soil so compact that vegetation will not grow upon the path for many years afterward. This protects the surface somewhat, especially if the trails have been made along the edge of a bluff, one above another, as is so commonly the case with the bison-paths. But this conservation is slight compared with the effects produced by another habit of this animal. All over the wide tract which has been traversed by the bison within the past fifty years there may be seen circular patches of grass in greater or less number, often now raised slightly above the surrounding surface in windy sections. Catlin, in his valuable work entitled "North American Indians," refers to these patches in the lower valley of the Missouri, and his explanation of their origin is no doubt correct. Without entering upon a lengthy discussion, it may be remarked that the bison is fond of wallowing in the mud, and no one can travel far in the West without meeting with what are there called "buffalo-wallows." These are shallow depressions, bearing some resemblance to the familiar "hog-wallow" by the roadside in the rural districts, though more nearly circular or semi-oval in outline. On account of the erratic habits of the animal large numbers of these depressions will be left, wherever the herds have rested in a suitable spot, to be filled with water by the rains, which, by evaporation, allows of the growth of grass to fix the soil by its roots, while the surrounding surface, if parched, as is often the case, may be degraded by the winds, leaving the grass-plats at a higher level.

II.—CUMULATIVE EFFECTS.

There are very few recent animal formations of much geological importance to be presented under this head, but there are several interesting and somewhat peculiar deposits of limited extent which deserve a share of our attention in this place. Next to the barren aspect of the great plains produced by the aridity of the climate, there is nothing which has so much to do with their appearance of utter desolation as the widespread accumulations of the bones of the bison and other animals which have been so recklessly slaughtered for the sake of the sport of hunting(?) them, or, at best, for the mere value of their hides. Millions upon millions of the skeletons of these animals now lie bleaching upon the surface, and it is almost certain that very many of them will become entombed much after the manner of their Eocene ancestors buried in the deposits of the Bridger group of strata. The present conditions for their fossilization are less favorable than during the Tertiary period, but many of the bones are already partly or wholly covered by the drifted sands, or by the growth of vegetation around them, and many have, no doubt, been transported by the streams and buried in the alluvial deposits.

"Buffalo-chips," as the dried dung of the bison is called, is common as a thickly-scattered surface-deposit in sections where it has not been covered by wind-action, though it is scarce along the line of the well-traveled roads, on account of its frequent use as fuel for camp-fires. In a few localities small deposits of guano exist in crevices in the rocks not exposed to the action of the rains. Opposite Camp 24, on a short tributary of Dry Creek, (Wind River Plateau,) I noticed in such a crevice a rich deposit of at least half a bushel. In many places in the Sierra Shoshone the weathering of the rocks has produced admirable crevices or fissures for the nests of owls, and frequently the walls of these are lined with a richly-colored glossy deposit of their excrement, mixed with the pellets of indigestible material ejected through their throats, according to their habit. Much of this is very resinous and not in the least offensive to nose or eye of one who does not know its real character. In fact, one of the party expressed a desire to taste a portion of it until informed of its true nature. This very strong resinous odor and quality is rather difficult to explain, except upon the supposition that the crevices are commonly shared by the owls with other birds which feed upon the seeds of the pines, though it is just possible that it is the result of secondary action, caused by the decomposition of the pine "needles" which fall into the crevices and become mixed with the guano.

The beaver may, perhaps, be properly credited with the indirect and unintentional formation of local deposits of alluvium by the damming of streams, but this effect is more than counterbalanced by its destructive tendencies. A few rather important but not extensive cases of fossilization by immersion in the basins of hot springs were noticed, but they do not require fuller notice in the present chapter, as further mention will be made of them in the section devoted to the geysers and hot springs.

III.—DESTRUCTIVE EFFECTS.

The beaver is probably entitled to take the lead in the work of destruction. These animals are still common in portions of the Yellowstone Park, and elsewhere, but the hand of man is already turned against them, and their works are, in most places, more numerous than themselves. It is unnecessary to describe these structures or their effects, for they are already widely known. Prairie-dogs and other burrowing animals are very commonly distributed throughout the region, and their actions have resulted in more or less destruction to the soil by bringing to the surface deposits of sand, which is scattered by the winds, and by injuring the solidity of the ground above their burrows. The destruction of vegetation by beavers occasionally has been quite general over small areas, but usually it has only accomplished a more or less beneficial thinning out of superfluous growth. Grasshoppers, in some sections, particularly on the Shoshone Plateau, have been instrumental in the destruction of vegetation to a remarkable degree, at seasons of the year when such devastation is often detrimental to the life of the plants.

CHEMICAL GEOLOGY.

A large number of interesting details remain to be considered, concerning which a quantity of illustrative material has been gathered, but which must be very generally treated within the prescribed limits of the present chapter. Much of this material requires careful chemical analysis for its complete elucidation, and this it has been impossible to procure, though the author indulges the hope that opportunity for its elaboration at some time in the future may yield valuable results in a department of geological science which assuredly deserves thoughtful consideration on the part of investigators. In the foregoing pages of the section relating to dynamical geology, very little has been said of the chemical changes which have taken place in the rocks since their deposition or of the important products which have resulted from chemical action.

The remainder of this chapter is, therefore, allotted to these subjects, including also some of the more important effects produced by the action of the atmosphere. No classification can well be adopted, and the various effects will be taken up in convenient order without regard to perfect system. In order to partially supply this lack, minor headings, in italics, are introduced for greater convenience of reference.

WEATHERING OF ROCKS.

It will not be necessary to speak in a detailed manner of the characteristic modes of weathering of the rocks of the various formations, but there are certain peculiarities in the effects of climatic and other influences upon special layers in some sections, which are of sufficient importance to merit attention.

Ozone in the atmosphere.—Many of the sandstones of the Green River group of Eocene beds, though white inside, weather reddish upon the exposed surface. The mere presence of iron in this rock seemed insufficient to account for the very marked change in color, but for several days no clue was obtained toward any more satisfactory solution. While engaged with Dr. Heizman in some preliminary analyses at our camp on Little Sandy River, I noticed that blue litmus-paper rapidly reddened upon exposure to the air, even when moistened with ammonia. Dr. Heizman, then and subsequently, kindly made several tests for ozone with iodized starch-paper, and found it abundant. This, then, may account for the excessive oxidation of many of the rocks of the Green River basin. This action is also noticeable in other sections where similar beds are exposed, but it seems to be mainly confined to the more compact beds, which, is, perhaps, owing to the fact that the more friable beds become more rapidly disintegrated and crumble before they can become colored. This will also explain the otherwise remarkable fact that the reddening effect is seen only upon those rocks not very highly ferruginous, though oxidation has taken place much more extensively in rocks highly charged with iron. If we seek to account for the presence of so great an amount of ozone in the atmosphere, it seems probable that it is due to the strong wind-currents or to some peculiar electrical condition of the atmosphere not accompanied by sufficient heat to prevent its accumulation.

Concretionary structure.

It is in the Tertiary rocks especially that the most interesting examples of nodular and concretionary forms may be found.

It would be no easy matter to enumerate the various peculiarities in the modes of weathering which have been induced by this structure, much less is it possible to describe more than a very few of the leading varieties, within the narrow limits of this section. In the Bridger group of beds large quantities of siliceous material are found, sometimes in compact cherty layers, but often in nodular masses, and frequently in concretionary forms with concentric or *concentring* layers. Sometimes these are lined with minute crystals of quartz, being in effect roughly-shaped geodes; others are little more than the fillings of cavities of irregular form, without separation into bands. Again there will be seen a huge concretion, composed of alternating layers of sandstone and intrusive chalcedony, the latter partly in "tears," partly massive or even crystalline. Very often in arenaceous and marly beds the concretionary structure appears almost to be entirely induced by the weathering of the rock, the oxidation of calcareous or ferruginous material giving rise to more or less concentric bands of color.

In the sub-Tertiary rocks concretions are often common. The Niagara limestone contains *jaspery* flakes and "drusy" cavities filled with beautiful agate concretions; *clay ironstones*, sometimes with plant-fossils, occur in the Cretaceous beds near Gray Bull River and at other points; and geodes of *calc-spar* are abundant in nearly all of the sedimentary rocks.

The volcanic rocks are very well supplied with these secondary formations, as instance the botryoidal geodes of the Yellowstone River, mentioned in the last chapter, and the great variety of interesting forms associated with the masses of silicified wood at Amethyst Mountain, on the south of the East Fork of the Yellowstone. Even the geyser deposits sometimes take on the concretionary, or, more properly, the concentric structure.

The principal forms of concretions will be found more fully described in the chapters relating to stratigraphy, under the heads of the different formations.

Influence of climatic conditions.—In winter the temperature of this region is severe but steady, and the surface is mostly covered with snow, which protects it to some extent from the effects of the various weathering influences. In the early spring and late fall the action of frost, in rending apart the rocks and enlarging the fissures, becomes an important element among the numerous dynamical agents, and it is probable that the alternate freezing and thawing which takes place at these seasons is productive of a large part of the weathering effects which are exhibited upon a scale of great magnitude in many parts of the district. Positive proof of the workings of this force from actual *observations* are wanting, but no one at all familiar with the ordinary results of such action will be disposed to doubt the propriety of the above statement when told that the necessary conditions of thawing and freezing are present during a large portion of the year in a high degree of intensity. Evidences of the slight movement of large masses of rock from the original positions by some force of this nature are very common. Some excellent examples of this action may be seen in the Wind River Mountains, particularly in the neighborhood of the nucleus, though it would be difficult to name a single rock-exposure in the whole district where such effects are not visible. Any person at all familiar with this process and its results in places in which freezing can take place only during a small portion of the year, will be prepared to recognize the dynamical importance of this agent in a country where there are but few nights, even in summer, during which the temperature does not fall below 32° Fahrenheit. In the central portion of the Wind River range the profound chasms have often been choked with immense accumulations of angular granitic bowlders which could never have been thrown down from positions in the cliffs without the intervention of the force produced by the expansion of water in assuming the solid condition. Steep cliffs of the Quebec group and the Niagara dolomite are almost invariably accompanied by large blocks at their base, which have thus been forced from their original places. The same features are observable in jointed exposures of the rocks of all the formations, but not always to the same extent. In many of the Tertiary rocks, as well as with some of the members of the metamorphic series and in certain argillaceous beds of the intervening formations, the strata are traversed by very numerous joints, which in a measure prevents the accumulation of water in the crevices for the formation of ice, and also leaves in the talus much less convincing proof of its mode of origin.

In the volcanic conglomerate in a large number of places there are good-sized cavernous holes, sometimes high above the ground. It is possible that some of these at the bases of cliffs may have been formed by wave action upon the shores of Miocene lakes; but many, and by far the greater number, have, undoubtedly, been caused by other agencies. Not a few show pretty clearly that they are the result of the action of freezing water in fissures, which has caused large masses to be dislodged at the weaker points from time to time without affecting the bulk of the rock adjoining the crevices. The alternate expansion and contraction of the rocks by differences of temperature in the days and the nights is, doubtless, of great consequence as a dynamical agent, although the actual effects produced are usually very difficult to ascertain. No special facts have been collected which can be offered with entire confidence, but the following remarks will enable the reader to form some general idea of the influence which these thermic changes must exert upon the rocks of this section: The difference between the day and night temperature (*i. e.*, maximum for day, minimum for night) upon the plains during the summer months is frequently as much as 30° or 40°, and it often becomes as great as 50° during the month of August. Dr. Livingstone* reports that the rapid contraction by cooling of rocks in Africa heated to a temperature of 137° Fahrenheit during the day, was sufficient to cause the breaking off of masses weighing even two hundred pounds in some instances. It may at least be suggested that this cause has been instrumental in the weathering of the rocks in the Rocky Mountain region to a greater degree than has generally been supposed.

Summary.—In general, it may be remarked that the Tertiary rocks show the effects of erosion and weathering much more clearly and extensively than the earlier rocks. This is due to two things: the greater activity of the eroding agencies, and the more fragile and soluble nature of the later horizontal strata. Another prominent cause is the rather abundant presence of formative and protective agencies in the moister mountainous districts, which are almost entirely absent upon the plains. Again, in the mountains there is greater resistance to the exercise of mechanical force, while below the chemical action is also increased, so that, upon the whole, the later series is exposed to far greater destructive influence, at the same time that its power of resistance is very small in proportion to that of the more ancient deposits.

CHEMICAL CHANGES AND PRODUCTS.

As before stated, a clear and comprehensive elucidation of the important subject of chemical geology cannot be given in these pages, but the present chapter would be incomplete without some reference to the more prominent changes resulting from chemical action, both in the direction of degradation of ancient deposits, and the accumulation of new formations from their waste. Hitherto, the chemical or physical processes of solution, condensation, evaporation, and precipitation, have been scarcely mentioned, in order that their effects might be more systematically considered in this portion of the report. For the sake of convenience, rather than from any natural method of arrangement, these subjects may be taken up in the order which has just been given.

Solvent action of water.—As water, in its passage over the rocks, takes from them the more soluble ingredients, its power to effect similar changes upon the rocks afterward met is more or less modified, according to a variety of circumstances. On this account it will be best for us to begin at the sources of the streams in the mountains and follow them down across the plains, that the ascertained results may be more clearly understood. Chemically speaking, there are two classes of mountain streams, which may be productive of somewhat different effects in the way of solution of the mineral ingredients of the soil and

* "Zambesi," pp. 492, 516. Quoted in "Manual of Geology," Jukes & Geikie, (third edition,) p. 376.

the rocks. To the first group belong those which are the direct products of the melting snows, and which pass off quickly to the plains over the surface of the ground. The second division comprises those which proceed from springs, in which the water has percolated through the soil, and has become partially saturated with the more soluble substances. In the region of the Rocky Mountains, where snow lies in the higher ridges almost perpetually, it is seldom possible to separate these two classes of streams, for very soon they will be found united in the same channels. There are, it is true, in the Yellowstone Basin, some important streams which proceed from springs alone; but in nearly every instance of this kind, the water passes for many miles over rock which is practically identical, mineralogically, with the formation in which the springs occur, so that the observed effects are much the same as in the snow-fed streams, which traverse the same district. A notable and not unimportant exception must be made in the case of the prominent aqueous products of the geysers and hot springs, which will receive special attention.

The extensive accumulations of decomposing vegetable matter in most of the mountainous districts furnish favorable conditions for the absorption of carbonic acid by the water, and this has no doubt had much to do with the excessive erosion which has taken place in the limestone exposures, and it may partly account for the general emergence of the streams from the mountains through cañons cut in the limestone. The absence of thick accumulations of soil is a very noticeable feature of a large part of the country, and this is due to the solution of the limestone, which is then carried off by the streams. Upon reaching the plains the waters become saturated with the more soluble mineral ingredients, though in seasons of freshets this may not take place until the stream has traversed the open country for a long distance. The water at this stage will contain alkaline carbonates which will have increased its solvent power, and even silica will be attacked and dissolved. In the Tertiary rocks there are many cherty beds and layers of the more soluble forms of silica which thus add their quota to the amount. In flood-seasons the banks of the streams are overflowed, and pools and small ponds are left in low spots when the current subsides. Rains and melted snow-water pass down through the crevices of the rocks, and the same ingredients are extracted, but with less of variety in each case than will be found in running water which has passed over many different rocks containing a great assortment of minerals.

Subterranean waters.—The presence of limestone-beds in such great quantity as to form the bulk of the Paleozoic and Mesozoic rocks as well as the regular but extended tilting of the strata, has produced fissures and underground passages, since enlarged by the waters, through which the drainage of the country is now partly effected. When the streams from these subterranean channels reach the surface in limestone districts, or in places where carbonic acid is forming from the decomposition of carbonates or of organic matter, bubbles of this gas (CO_2) are sent off in quantity. Springs of this kind exist in many parts of the Yellowstone Basin and in other portions of the volcanic district. Yellow Water Creek, a southern tributary of Gray Bull River, originates in a chalybeate spring which is very highly charged with carbonic acid. The hot springs below Camp Brown also evolve considerable quantities of this gas. Several cold sulphur-springs issue from the Triassic and other rocks containing gypsum as a deposit or in process of formation by the decomposition of pyrites. Near the left bank of the Little Popoagie, and also at Camp Brown, thick oil issues from the earth, probably connected in some way with the Cretaceous coal or lignite beds not far distant in either case. Both of these springs are located within or near a prominent fold involving the Subtertiary strata. At our camp on Spring Creek, at the southern base of the Owl Creek range, several springs of bitter "alkali" water afforded the only means of quenching thirst. Sour Creek entering the Yellowstone above the falls, from the right bank, Warm Spring Creek, nearly opposite, and all the prominent streams of the geyser basins, are highly charged with mineral ingredients held in solution, largely the result of the action of subterranean waters.

As might be inferred from the horizontal disposition of the Tertiary strata, and from their extensive erosion into buttes and benches, springs are seldom or never present over the area occupied by them, except in cases in which they may originate in other formations and reach the surface through the Tertiary beds.

The most important and extended results of the action of underground water are exhibited in those sections where heat has accompanied its movements, as in the geysers and hot springs of the National Park which fall to be described in a subsequent portion of this work.

Results of condensation and evaporation.—In the Tertiary districts the surcharged streams, and particularly the stagnant pools produced by the overflow, soon become condensed by the heat of the sun and the drying action of the wind. In soils which are not argillaceous, or in those which are covered with turf, this results in the production of a sirupy saline liquid, and finally, if the evaporation be sufficiently extended, the so-called "alkali" deposit is formed. In clays the evaporation is retarded and chemical changes doubtless take place continually. If the saline accumulation be excessive, or if the evaporation be insufficient to dry the clay, a bog or slough is the result, and these are commonly known as "alkali bogs" and "alkali holes." Along the edges of the streams and upon the overflowed grass after the receding of the waters, a deposit is formed which is usually reddish or brown at first, from the presence of iron, becoming white or grayish upon exposure to the air and drying. This is usually called "alkali," although it frequently contains scarcely a trace of potassa or soda. A specimen of this deposit gathered by myself on June 20, 1873, from a fresh accumulation on Little Sandy River, was qualitatively analyzed the same day by Dr. Heizman and myself with the following result:

Alumina, very abundant.
Magnesia, in considerable quantity.
Lime, in small quantity.
Iron, small amount.
Carbonic acid, considerable.
Sulphuric acid, very abundant.

In a peculiarly weathered concretion exposed in a bluff or butte near the same locality a quantity of siliceous marl was inclosed by a deposition of *chalcedony* in "tears." An analysis of the marl yielded:

Alumina, in considerable quantity.
Magnesia, in considerable quantity.
Lime, abundant.
Iron, small amount.
Silica, basis of the marly deposit.
Carbonic acid, in considerable quantity.
Sulphuric acid, in considerable quantity.

The very large quantities of "alkali" which exist so widely over the plains as an efflorescent deposit have probably been formed by the evaporation of former extensive lakes and ponds left over the Tertiary basins by the draining of the ancient lakes which once covered the whole area. Some of these deposits are of great thickness, but none worthy of more special notice were met upon our line of march. The same process is in operation at present, as described above, but the results are small when compared with what was accomplished in ancient times, because the streams now carry off the greater portion of the soluble material. In these old ponds also are found the readily soluble ingredients as well as those which are sparingly soluble, while the streams leave behind only the substances which are not so easily held in solution.

The various deposits of the hot springs and geysers to be hereinafter described might properly be discussed under this head were it not more convenient to consider them in a chapter by themselves.

Precipitation.—The only prominent example of undoubted precipitation occurring in a natural aqueous solution along our line of march was noticed in a portion of Yellow Water Creek.* The water is slightly alkaline, and contains or receives a large amount of iron from an ore-bed near its source. Much of the iron is precipitated as ferric hydrate, ($Fe_2 O_3, H_2 O$.) This settles to the bottom, but it entangles carbonic acid which struggles, as it were, to free itself, thus lifting the precipitated mass toward the surface a little way. A few rods below, the water becomes clear and more palatable, from which it would seem that the iron had by this time exhausted the alkaline principle so that the precipitation can no longer take place. This phenomenon is very interesting and quite remarkable.

Nothing but the absolute necessity of completing this report within the allotted time has compelled the omission of not a little in the way of facts bearing upon the important subjects of this chapter. An endeavor has been made, however, to introduce those facts and observations of the writer which are of the greatest interest, and such as will most aid in connecting together the several parts of the report in a harmonious whole.

* Precipitation occurs commonly in regions of hot springs and geysers also, but this subject will receive more attention beyond.

NOTE EXPLANATORY OF THE COLORED GEOLOGICAL MAP.

The general distribution of the various geological formations in Western Wyoming is sufficiently indicated by the coloring upon the accompanying map, specimens of the tints being separately given with their proper numbers.

It should be remarked that the author lays no claim to strict accuracy in the delineation of outcrops, a task which it is manifestly impossible to accomplish, unaided, in a single season. Believing that such a map, however imperfect in minor details, will serve as an aid in the more complete understanding of the text of this report, and cherishing the hope that it may hereafter prove of some slight value as a guide for future laborers in this field, it is offered as an exponent of the geology of this region with the conviction that it is as nearly correct in its main features as it is possible to make it without more extended research. In fact it is just such a map as the author would use as a basis of operations if he were again to enter the same field.

As far as possible the introduction of conjectural material has been avoided, but in most cases it will be fair to consider that the number of *known* facts is in inverse ratio to the distance from the trail of Captain Jones's party. In some cases the map of Dr. Hayden, accompanying his report to Captain Raynolds, has been followed outside of the limits of this reconnaissance upon the northeast. Prospective maps from competent authorities will doubtless soon render possible quite accurate delineation of the prominent features in the west and south of the district. For this reason the former area has been left uncolored, and the structure of the latter has been but roughly designated.

REPORT ON MINERAL AND THERMAL WATERS.

BY ASSISTANT SURGEON C. L. HEIZMANN, U, S. A.

QUALITATIVE ANALYSES OF RIVER AND SPRING WATERS, SPRING DEPOSITS, ETC.—THERAPEUTICAL CONSIDERATIONS.

SIR: I have the honor to submit the following report of analyses of spring and stream waters, &c., examined *en route* during the summer of 1873 to and from the headwaters of the Yellowstone River through Northwestern Wyoming Territory, together with general observations of the medicinal qualities of the springs within the section known as the National Park.

As a thorough description of the trails and surrounding country will be included in the topographical and geological reports of the expedition under your charge, I confine myself to allusions to the former in localizing waters, and advise references to the latter for particular geological features, instead of incorporating in the report a reiterated account of the route. The date and number of the camp, therefore, will serve to fix the geographical position of streams and springs as well as to guide to the correct appreciation of the natural relations. Moreover, the thermometrical record, which is of the greatest import in the proper estimation of the medicinal value of a water, will be found very incomplete; this on account of the desultory character of observations, necessitated always in a comparatively new and unexplored country. However, the meteorological report of this expedition can be consulted, but it must be remembered that careful readings of instruments for a day or a month in one place are now-a-days deemed insufficient for a strict understanding of climate and its influences. Reference can also be made to the excellent reports and tabulated statements of Dr. A. C. Peale in Hayden's Reports of the United States Geological Survey for 1871 and 1872.

In consequence, and to make easy by a connected account, I have adopted the field system, a recital of observations and notes day after day. A few general quantitative analyses, however, subsequently made, are thought necessary to be incorporated in the body of the report. After our return, I found in Hayden's Report for 1872 analyses of deposits which cover a great deal of the ground of the Yellowstone Basin, and you will find, therefore, that I have only noticed such as have some special relation to a water or have not been analyzed before.

Our journey from Fort Bridger, through South Pass, to Camp Stambaugh, (June 12 to June 24,) over one of the well-worn overland emigrant-routes, crossed the eastern section of the Green River Basin, which is mainly traversed by Green River and five of its branches. All of these streams were greatly swollen and they impeded our progress, particularly the Sandys, whose origin is in the foot-hills of the Wind River Mountains, and which, then violent torrents, in September following had an insignificant flow. The water of these streams at neither period is acid nor alkaline, though bitter to the taste, and causing a burning sensation to the skin. One fluid-ounce of the water of the Little Sandy contained in suspension one-half grain of sand, all of which deposited one hour after standing. The reactions of the clear water showed only the presence of magnesia and sulphuric acid. A bit of the so-called "alkali dust," a white or grayish deposit taken from the banks of this stream, contained lime, magnesia, iron, alumina, sulphuric and carbonic acid, and silica.

Here (June 21) was first noticed a peculiar behavior of the blue litmus-paper used in testing, that of showing after immersion and short exposure to the air an acid reaction; even after wetted with ammonia water it turned red after a few seconds free exposure.

Ozone papers became of a deep brown color in a few hours, and thus accounted for the phenomenon, which was verified afterward at Camp Stambaugh, and the higher localities of the route, before entering the Yellowstone Valley.

The waters of the Sweetwater, (June 23,) of the streams supplying and those about Camp Stambaugh, (June 24, July 1,) viz, Beaver, Twin Creek, Little and Big Popo-agie, at this season, and at the points crossed, were pure mountain-streams, exhibiting no reaction though they carried different amounts of sand. In contrast the valley (5,560 feet above sea-level) of the Little Wind River furnished novelties, and I think my regret on leaving it was shared by all of the members of the expedition. The abundance of material for the geologist, botanist, and meteorologist in it makes it a desirable point for their work; and I have no doubt of its possessing advantages for study and discovery for the medical hydrologist, excluding the sources already known there—one large sulphureted lime, (*sulphuric* calcique,) several cold sulphurous springs, and one carbureted and oil spring—but including its mild and invariable climate of summer, (mean average temperature for July, August, and September, 1873, 62°,) and its beautiful surroundings.

The sulphureted-lime spring, two and a half miles from Camp Brown and near the bed of Little Wind River, into which its water flows in a not insignificant stream, is elliptical shaped, (315 feet and 250 feet diameters,) neutral, and contains free carbonic acid, (abundant,) sulphuric acid gas, lime, magnesia, soda, sulphates, chlorides.

Its deposit, hard, stratified, yellowish, contains lime and magnesia carbonates, some chlorine, and a little (not deposited) silica.

The waters, used for bathing only, have the reputation of curing rheumatism and some skin-diseases, and are similar in composition and effects to *Aix-les-Bains*, (Savoy.*) Even a short stay in them for the first time makes one weak, dizzy, and nauseated; afterward, however, after a sensation of depression (rapid beating of the heart) there occur agreeable feelings of cleanliness and strength with mild thirst. The following observations of temperature, taken by Dr. Thomas G. Maghee, United States Army, are interesting:

*Vide Barrault, Eaux Minerales.

Date.	Daily mean, in degrees Fahrenheit.	Temperature of the Hot Springs, in degrees Fahrenheit.		Date.	Daily mean, in degrees Fahrenheit.	Temperature of the Hot Springs, in degrees Fahrenheit.	
		At the shore.	In the center.			At the shore.	In the center.
1874.				1874.			
March 18.....	16.[illegible]	106.8	109	April 3.....	35.66	107.2	109.1
March 19.....	13.33	104	106	April 4.....	33.66	104.2	106.2
March 20.....	24.33	107	108.8	April 5.....	29.33	105.4	108
March 21.....	18.00	107.8	109	April 6.....	24.00	108.8	109.9
March 22.....	24.33	106.4	109.4	April 7.....	33.33	108.4	110.1
March 23.....	29.66	107.2	109.8	April 8.....	38.66	106.9	108.5
March 24.....	32.00	106.4	108.9	April 9.....	40.33	108.4	110
March 25.....	35.33	106	107.2	April 10.....	44.33	109.1	110.3
March 26.....	31.66	107.6	108.1	April 11.....	45.66	107.1	109.2
March 27.....	36.33	109.9	110.1	April 12.....	43.33	101.1	102.4
March 28.....	27.33	103.6	106	April 13.....	38.00	97.2	99.5
March 29.....	27.33	106.2	109.4	April 14.....	34.66	104.6	106.8
March 30.....	25.33	106	107.5	April 15.....	30.00	105	107.5
March 31.....	23.33	107.1	109	April 16.....	32.33	105.1	106.1
April 1.....	30.00	108.6	110.4	April 17.....	28.00	107.6	109.2
April 2.....	36.33	107.2	109.4				

The cold sulphurous springs arise from the base of the foot-hills of the mountains, about six miles from Camp Brown. One, (Tesson's)—temperature 50°—blackish brown deposit, contains lime, magnesia, carbonates, chlorides, sulphates, and abundant sulphureted hydrogen. Doctor Maghee writes that he found its water to be diuretic and mildly laxative.

T e carbureted oil-spring about one mile from the camp is remarkable only for its oil and great amount of asphalt making up its shores. With the gases—sulphureted hydrogen and carbureted hydrogen (?)—rising from its sandy bottom (water two feet deep) spring up to the surface plenty of oil-globules, which, floating, are blown ashore, and there become a hard asphalt after some time. The oil, taken as it arises, after evaporation of the water, loses on burning exactly 90 per cent. The water, I think, possesses no interest in a therapeutical point of view, as the bathing or drinking facilities are small, it being constantly filled with the rising globules of oil.

After leaving the Little Wind River Valley and crossing Sage Creek, (Camp 20) Wind River, (21 and 22,) and Dry Creek, (23,) all of no noticeable interest, we passed over the Owl Creek Mountains, which were remarkable for the scarcity of springs and water-courses. One spring, (Camp 25,) the only one on our route over, gave very little water, very hard, and intensely disagreeable to the taste. The water of the Beaver, (28,) a small stream, and Grey Bull, (29,) possessed nothing worthy of note, but a series of little springs were found a few miles south of the latter river, which form a creek (Yellowwater of the Indians) flowing into it. Their sides and bottoms were of deep yellow; their water contained an abundance of iron, some lime, magnesia, sulphuric acid, sulphurets, and carbonic acid combined and disengaged—were neutral, and of 50° temperature. The exterior of their deposit (carbonate of iron) became, after short exposure to the air and light, a white impalpable powder.

Camp 30, July 24, was made on a small stream flowing into the Stinkingwater, and formed by a large number of mountain-springs, with a temperature of 50° (air 70°) neutral and containing lime, magnesia, sulphuric and carbonic acids. The deposit of these, tasteless, was scant, white, and reacted for carbonic acid and hyposulphuric acid.

Camp 32, July 26, was made on the Stinkingwater, near which we found a large spring raised two or three feet above the ground, with an abundant flow of a blackish water of great specific gravity, of strong sulphurous smell, (temperature 56°; of air, 75°,) and depositing black. The water contained soda, sulphates, and sulphides. The deposit was made up of sulphur and hyposulphite of soda. As we approached the river, by Cretaceous bluffs, an odor of sulphuretted hydrogen became distinctly perceptible in the air, observable several miles away. A number of extinct springs occur here, but the existence of numerous active ones near, besides the last mentioned, was indubitable. The Indians stated that many large similar ones could be found at the junction of the forks, about twenty miles east of our trail.

The river, North Fork, which we ascended July 26, August 2, was fed by many pure mountain-streams, flowing abundantly from both the north and south. These often consisted of a succession of falls, sometimes of 100 feet, over the volcanic sides of the cañon; most of them, however, were furious torrents, over steep inclines, broken by great masses of rock.

At the headwaters, where the sources were attainable, the temperature of these was found to be invariably 50°, (air 71° to 80°.) They were pure, or nearly pure, as they exhibited no reaction. The water of one spring, 100 feet beneath the top of the pass over the mountains into the Yellowstone Valley, gushed from a hole in the perpendicular rock and made a perfect fall of 20 feet before reaching its first flowing surface.

The pass into the Yellowstone Basin, August 2. At no time or point of our subsequent trail within the Yellowstone region was spread out for us a more complete or effective view of it than here in the Sierra Shoshonee Mountains. Sufficiently above timber-line to meet with no obstruction, we in wonderment looked upon the great placid lake glimmering in the sun, imbedded in ridges, among bald peaks and timbered hills; a great flowered lawn here, a dense forest there. A large ascending mass of steam marked the Firehole section; others, smaller, the localities of less thermal activity; the course, entrance, and exit of the river, the whole water-shed of the valley as an amphitheater; the scene backed by the Teton range, with its sharp-cut and jagged contour, the three sisters of which stood out grandly in the clear sky.

Nor was our curiosity less gratified when, after a slight descent, we camped (37) (9,000 feet) on a decline whose beautiful clumps of pine and spruce, running streams, and plots variegated by flowers, were suggestive of a cultivated park. Around us buried in the woods we discovered a number of circular springs, 10 to 15 feet in diameter, each on a small terrace. The water of these (temperature 37°–42°) was clear and limpid, revealing a soft grayish bottom pierced here and there by little round holes from which bubbles of gas ascended at intervals of one minute exactly. It showed no reaction of any kind, while the gas collected was suspected to be sulphurous-acid gas, on account of its bleaching litmus paper. Tests for carbonic acid and sulphuretted hydrogen were frequently but fruitlessly applied. These springs were remarkable because of being *sui generis*, none anologous having been found afterward in the other hills or the valleys of this region. What relation they bear to the thermal springs immediately below them (Turbid Lake) could not be discovered either by their deposits or contents in solution. Their outlets gave egress to a small quantity of water, which soon joins the larger streams from the melting snows of the summit.

Turbid Lake is an instance of a class of many thermal *foci*, others existing near Orange Creek, shores of Yellowstone Lake, west side of Yellowstone River, &c., though the surface involved and degree of activity differ in all. A common reservoir for two mountain-streams and innumerable hot springs, it supplies a good stream to the lake. Its clay-colored surface was in constant agitation by the bubbling gases, carbonic acid, and sulphureted hydrogen; its temperature near the shore varied whether taken near the entrance of a hot stream or not, though only a few degrees, the lowest being 60°, highest 70°. Reactions were obtained for iron, alumina, magnesia, sulphates, and sulphides.

The shore of this pond presented, as compared with that of the others to be mentioned, a diminutive representation of the activity of its class. A scaly surface, almost 100 feet wide, was broken by countless springs of all shapes and sizes, temperatures, contents, and deposits, from the emission of a fine puff of steam, or little bubble, to a spring a few feet in diameter, varying from 66° to 192°, sometimes two within six inches of each other differing 20° to 30°, and containing in different proportions lime, magnesia, iron, and alumina, sulphates, chlorides, sulphides, and silica. Indeed, some of the waters tested failed to show the presence of lime or iron, and alumina. Their deposits or surfaces about them, in all cases brilliantly colored, were as various; green, (*Confervoidea*,) yellow, red, or white prominently; and the forms of them were as many as the colors, dry scaly layers, glazed viscous precipitates, and villous or noduled masses. The last, for the most part, consisted of a green base covered with white fungiform protuberances, the manner of the formation of which I could at no time suspect.

A little southeast of the lake, but in the same class, were a number of larger springs than those immediately about it, whose waters flow into it, and two mud-craters in some way connected with it. On the rim of its barren shore, unusually near timber and grass, was a circular hole 20 feet in diameter, borders clean cut, filled to within 1½ feet of its top with a steaming, bubbling, and thudding mass of seemingly plastic and drab-colored mud, (184°.) It had no visible outlet, but its relation to the common reservoir of the surrounding springs may be guessed from the fact of the hollow-sounding surface 25 feet above it, which was broken by small orifices, puffing steam, lined with sulphur crystals. At times, or spasmodically, the mud in the middle of this hole was thrown a foot above the level surface; and strewn on the ground near its border was found a number of chunks of sulphur which is nearly pure, being nearly all soluble in benzole. A specimen of this mud contained iron, alumina, lime, (apparently in small quantity,) magnesia, sulphates, hyposulphites, and sulphur.

The companion of this mud-spring, south of it, differed from it in no respect except by being smaller and puffing like a steam-engine.

Three water springs of large size were found on the banks and in the bottom of one of the mountain streams running into Turbid Lake. One of these was remarkable and curious in its violent ejection of hot water 3 to 5 feet from the midst of a cold, rapid stream. The others (180°–182°) gave large flows to the creek from slightly-elevated banks, but from the enormous mass of deposit (some nearly pure sulphur) about them, I think they will soon become extinct.

The banks of Pelican Creek, which we followed to its mouth to Camp 38, presented for the most part very little of importance until a few miles from its entrance into the lake, where were found remains of extinct springs and a collection of active sources in many respects peculiar.

From a high, large, red bank, flowed into the creek two hot streams beginning in little springs, (average 124°,) depositing the same noduled masses as some waters at Turbid Lake. One, after flowing a few feet, disappeared through a small hole in the bank and re-appeared 70 paces below, when it continued openly its course to the river. Although a few of these springs steamed and gave off the odor of sulphureted hydrogen, none bubbled carbonic acid. Curiously, the red bank contained carbonate of iron. The Indians with us used its material for pigment to ornament themselves and horses. It is of mixed consistency, color, and texture; portions being soft and oily to the touch, others hard and irrefragable; from dark to light red, with purple and brown intermixed; compact or loose; and these differences not owing to the depth from which taken. It is partially soluble in water, (chlorides of lime and magnesia,) partially in acids, (carbonates of iron and lime.) A portion of the hardest intermixed with white, contained: Silica, 70 per cent.; iron, 29.54 per cent.; lime, .13, with traces of magnesia. The hard white noduled deposit from the bed of the flowing spring, a few feet from its source, lost on ignition 9.50 per cent. and contained 75.55 of silica, with iron and alumina, lime and magnesia. A soft green, white, and brown granular specimen, taken from a spring near this, lost on ignition 11 per cent. and contained 83 of silica and other similar contents. The waters contained iron and alumina, magnesia, sulphates, and chlorides.

Here in one of the average (124°) springs animal life was active.

Between the mouth of Pelican Creek and Steamy Point, on the shore of the lake, is a chain of springs (100°–192°) some steaming, most of them with lead-colored deposit and water, all bubbling carbonic acid, and only some sulphureted hydrogen. In one I noticed the gases rising from small holes similar to those of the springs at Camp 37, and from the top of little cones in its bottom. One, (106°,) the largest, and like Turbid Lake a reservoir, bubbled along its shore, while its banks were filled like it with small active, and remains of small extinct springs. One, 20 feet from the last, 3 feet in diameter, temperature 120°, lead-colored deposit, reacted for sulphureted hydrogen, iron, alumina, and soda, sulphides, sulphates, and hyposulphites, and became very acid after standing four hours.

Nearer Steamy Point another like series of springs around a bubbling pond (76°) exists. Steamy Point, covered with large vegetable growth, contained a small number of springs, (184°–192°,) all bubbling violently, and a few holes in the side of a rocky bank, from which issued jets of steam, but little water, depositing a yellowish-brown on the surface. At times, irregularly, the puffing steam was more violent than at others. The ground about these was insecure, as about the mud-springs. The water of one spring, (192°,) lead-colored and slightly acid, (specific gravity great,) contained lime, iron, and alumina, sulphur, sulphates, and hyposulphites. Its smooth, convex bank, 1½ feet deep, was composed of a soft, green, amorphous deposit, which, after having lost most of its water by long keeping, and breaking down into a dry powder, lost on ignition 9.01 per cent. and contained a large quantity of silica, some sulphur, and the same constituents as the water, excepting the hyposulphites.

From Camp 38 we followed the course of the river, east side, downstream, through thick timber and by pure springs, and over beautiful streams (42°) flowing into the river. *En route* were passed many sulphurous springs also. At Camp 39, which was opposite the head of the cañon, were numerous extinct and active springs, the latter materially aiding in the formation of a clear, rapid stream, (70°,) which was very acid and astringent, depositing reddish yellow, and running by a great mound-shaped bank containing both the active and extinct springs.

Its water, taken from below all its sources, contained only iron and alumina, sulphates and chlorides. It is formed by several groups of springs about Camp 39, closely allied, judging by the great prevalence in all of iron and alum. Two springs in one set north of us, (156° and 158°,) each 4 or 5 feet in diameter, muddy bubbling contents, with no outlet visible, emitting a strong odor of sulphureted hydrogen, and ejecting with it sulphurous-acid gas, contained lime, iron, and alumina, magnesia, sulphates, sulphides, chlorides, and hyposulphites. They are surrounded by countless springs and mud-vents of all temperatures; the contents of one of the latter, a very large one, are colored like molasses, and have in agitation a curious intermittent thudding sound. Of the others, the shades are as various as their temperatures, black mud and lead, light and deep green, colorless, &c. Six of those with light green water, (88°–100°,) having an outlet, and very acid, gave only reactions for iron, alumina, magnesia, (abundant,) sulphates, sulphides, (slightly.) Two in the same group had water, blackish, (deposit drab-green,) boiling (170°) and bubbling so violently in deep oblique holes as to be thrown out in great waves, slightly acid, and containing iron and alumina, sulphates, and sulphides. The sulphur was hardly appreciable after the water was taken out, but together with hyposulphites was deposited in great quantity.

Another group, separated from the last by a small ridge filled with the remains of springs and apparent geysers, possessed not so many springs but all of the same kind excepting one, (140°,) which had a colorless water, more acid than any tested, and contained iron, alumina, sulphates, and sulphides, (slightly).

All of these springs tested emitted sulphureted hydrogen, (some steam and sulphurous-acid gas,) the deeper-colored the greater quantity, but none evolved carbonic-acid gas. The deposits of all contained silica in various though small proportions.

Sparsely scattered along the east bank of the river at the bottom of the cañon there are some small springs, pouring their water directly into the river. Sulphureted hydrogen was freely emitted from all, carbonic-acid gas from only a few. Their salts were the same and as differing as those of the springs at Camp 39 and on Turbid Lake. One, however, was remarkable in being something like a geyser in its action, that of ejecting five feet transversely through the air and directly into the river a thin stream from the top of a conical eminence.

August 10—*Camp* 40.—We found a number of springs on the bank of Orange Creek, which where we crossed had a fine appearance, flowing rapidly between rocky and timbered hills, over a bright orange, siliceous bottom, though its valley is redolent with odors of sulphurous gases. All of these differed in temperature; two of the largest, within a few feet of each other, were of 170° and 196°. The first (green-yellow deposit) sending a blackish water into the stream, contained iron and alumina, lime, sulphates, hyposulphites and sulphides, and silica, which last deposited in enormous quantities.

The largest and most numerous steam-jets we saw in the Yellowstone region were found here, in a gap giving egress to a small stream arising from them and flowing from the south into one of the forks of Orange Creek. Its sides and bottom, of deep-red and yellow, included about 50 acres and were filled with hundreds of steam-jets, but contained only a few small holes bubbling hot water. Over the greater portion of its surface the ground was very insecure, often breaking under the tread and exposing soft sulphur crystals, from the midst of which issued a new jet. Hard chips of sulphur, in very great quantities, are strewn about. Scattered in this gorge on firm foundation were rocks of all sizes, some 50 feet high, from beneath most of which violently puffed steam which deposited on the roofs sulphur crystals. There were two very large vents, whose action could be heard a great distance, that of throwing columns of steam from caverns half-way up the declivity, 200 feet into the air.

These, together with a few others not so large, emitted small, clear streams with variegated deposits, which united to form the main one through the gap. Water taken about 20 yards from the greatest jet, as near as one dared to venture, had a temperature of 144°, while the temperature of the steam issuing from the smaller and accessible vents was 196°; of the air 59°. It contained iron and alumina, magnesia, probably, and sulphates.

Six miles from Camp 40 on our trail was found a group of springs in a ravine the upper half of which was filled with extinct springs, where the water flowing through it was potable, the lower half with active sources greatly acidifying it. These were (contents, deposits, &c.) exactly like the last-mentioned. Farther on another group similar to that about Turbid Lake exists. A large central pond, water 100°, with an outlet giving a considerable flow toward a small creek, is surrounded by many small, clear, bubbling springs with nearly the same variety of temperature (86°–150°) and with the same deposits. Near it is a mud-hole (40 by 25 feet) in violent agitation, so much so that the mud in its center is sometimes thrown 2 to 3 feet in the air—great waves of mud being thrown with considerable force against and over its sides—but in other respects having the same characteristics as those at Turbid Lake.

No waters of importance were met with during our journey over the high divide to the East Fork of the Yellowstone River from the camp on which we visited the celebrated Hot Springs at Gardiner's River.

The region about the East Fork of the latter river is one of great beauty. The hills are broken by the stream, which nearly the whole distance to its mouth runs through cañons and over precipices, making fine falls constantly exposing their structure of volcanic rock, basalt, and trachyte, topped by columnar ridges of metamorphic limestone; the falls and rapids alternate in quick succession and give life to the scene. As we approached the mouth of this fork the Great Hot Springs appeared on the west side of the river itself, several miles away, as an enormous dirty-white projection from between two hills, looking like the slag-pile of a giant furnace. Indeed, one's impression is unsatisfactory even after crossing the river at a point facing the springs, and admiration only arises when standing almost at the foot of the great mass of terraces, basins, and cascades.

GREAT HOT SPRINGS, GARDINER'S RIVER.

As these springs have been described and mapped several times as well as a few days' sojourn in their locality permitted—for there is still a great deal of untouched material of all kinds to be observed and examined—I confine myself to a few general remarks.

Each basin is perfect, excluding such as are in a state of forming, composed of crystal-covered walls, from 6 inches to 6 feet high; its sides in columns and consequently its rim scalloped, 1 inch to 5 inches thick; its depth varies 1 inch to 3 feet, its length or breadth from 4 feet to 12 feet. Sometimes its material is snow-white, (when it has just been deprived of water-supply,) at others grayish, (extinct sometimes,) at others brilliant brown or yellow with green-trimmed edges, (when it contains water to its rim, which is either constantly supplied from a main source above, or, if this is cut off, percolates from others in its vicinity, probably through its own bottom, signifying, I think, early extinction.) The deposit on their bottoms is as multiform as the whole system of crystalization. A thin sheet of pure white, looking like rice-paper and breaking to the touch, is very abundant; little white spheres $\frac{1}{4}$ to $\frac{1}{2}$ inch in diameter, with one small opening, their exterior rough, somewhat like a mulberry, interior smooth—also very fragile—exist in all, and in some cover completely and form the bottom. Many tubs are filled with coralloid crystals springing from the bottom and branching like trees or spreading over the surface in all conceivable shapes. In one basin I observed, attached to a beautiful sandy bottom, an abundant, very thin gelatinous growth 3 inches high, shaped like a mushroom, and of the same bright yellow color as the oscillating silky substance found more frequently. The white deposits are sheets of lime, (mainly,) rapidly precipitated, beneath which become entangled bubbles of rising gas which slowly molded the spheres. Other forms are accounted for by crystalization and deposit of the contents of the water, sometimes modified by intermixture, with minute organic matter, or even by the presence of large growth, as twigs and leaves blown into a basin.

The colors of the granular contents of many bottoms differ wonderfully; white, violet, pink, flesh-color, brown, red, green, yellow, &c. As noticed by observers before, the basin temperatures were curious, often those of two lying together differing 30° to 40°, and the colder, though, in general, not always the farthest removed from its source. Of these the lowest I took was 70°, the highest 144°, with all shades between.

Between basins are smooth covered slopes, which contribute mostly to the general cascade appearance. They are nearly pure white when the water is falling over them. Their structure is as various and as wonderful as that of the basins—generally small radiating crystals giving the mass an asbestos-look, (when the water flows over it from basin to basin;) sometimes a smooth surface becomes rugose by ripples coursing in all directions, (abundant specimens among the extinct springs;) sometimes the exterior is shaped like scales overlapping each other—mailed. Often these slopes terminate abruptly without connecting with a basin below or with a more horizontal surface; their under surface, then, is composed of small, many-colored stalactites, finely fringed, and having the appearance of wings, feathered horns, &c. Sections of level floor have the same structure, forms, colors, &c., but are thicker and have larger stalactites beneath. The temperatures of the sources taken last year do not differ materially from those tabulated by Dr. A. C. Peale, (Hayden's report for 1872,) excepting one, which we succeeded, after considerable trouble, in taking at the center where the water was violently agitated and thrown a foot or more high, (No. 22, 9th terrace of Peale);—it was found to be then 164°. All of the springs on all of the terraces evolved carbonic-acid gas, sulphureted hydrogen, and vapor, all in different proportions. The water of one little spring, on the 12th terrace, (150°,) alum taste and acid, contained silica, lime, magnesia, iron, alumina, carbonates, (slight,) sulphates, sulphides, and chlorides. The water of the springs (13th terrace) flowing from geyser-like tubes on the largest mound contained silica, lime, iron, carbonates, chlorides, and sulphides. There was no spouting, during our stay, from any of these, as witnessed by Peale in 1871, although now and then a rumbling sound from beneath the mound or the more violent gurgling of one or two sources seemed to threaten such an eruption.

A deposit, yellowish-green, scraped from the surface of one of these mound-springs, nearly all soluble in water, contained very little silica, iron and alumina, lime and magnesia, carbonates, hyposulphites, sulphates and sulphides. The white deposit of extinct springs near the "Liberty Cap" reacted for carbonic acid (very abundant) and lime, with a trace of iron and very little silica.

A pure white deposit (powder) of one of the springs on the 11th terrace contained lime and magnesia, carbonates, trace of iron, trace of sulphur, and very little silica.

August 23—*Camp* 44.—Before reaching this point a camp was made on Cascade Creek, which is of no special interest outside of its beautiful fall into the Yellowstone River. Leaving it and the falls of the river, we passed the locality named Mud Volcanoes, where were a number of springs of the same class as and similar to Turbid Lake. Here, flowing into the river, is a small creek, (Alum?) which we followed to near its source in the little divide between the Yellowstone and the Madison, (Firehole.) All along its banks were hundreds of boiling and bubbling springs and remains of extinct ones, all of which may be classed with the last, although there is a greater profusion of clear alum-springs evolving only sulphureted hydrogen, intermixed with the others, than elsewhere. One, near the head of the stream, was for the most part walled (6 feet high) by its deposit on small timber, which, partially silicified, gave it the shape of a yellowish-brown snaggy cone. Although not exactly like a geyser, it nevertheless threw constantly its water (194°) with great violence against its sides and 8 feet into the air. It contained lime, iron, alumina, magnesia, sulphides, sulphates, and chlorides, and evolved no carbonic acid but sulphureted hydrogen. All of the springs surrounding it, very numerous and close together, evolved carbonic-acid gas, but, strangely, some of them only it and sulphureted hydrogen. The creek above, besides being supplied by many small springs (10[illegible] 180°) on its banks, contains in its bed many bubbling carbonic-acid gas but no sulphureted hydrogen.

The temperature of the running water here was 84°. However, a tread or the mere piercing with a stick of its sandy bottom anywhere within one-half mile, started a thin, hot, and unbearable stream containing carbonic-acid gas, but no sulphureted hydrogen; of course, as its flow was only momentary, its relative temperature could not be got, but the temperature of the surface-sand where no visible spring existed was the same as that of the water, 84°. Above the point where camp was made and where this phenomenon gradually disappeared, the water of the creek was pure and potable.

Camp 45—*August* 24—in Lower Geyser Basin, and on a little *pure* stream running into the Firehole River. On the hill back of this camp, 100 feet above the open-geyser area, and surrounded by a large growth of timber, was found a number of springs, which for beauty exceeded all in this locality; some large, perfect-shaped funnels, 20 to 50 feet in diameter, at the bottom of which, through the transparent water, could be seen the orifices proportionately as large as the spring, (largest having one of about 1 foot diameter,) venting great bubbles of carbonic-acid gas and vapor. From any point, whether as one approaches them or is directly over them, their bright azure-color strikes one even more pleasantly than the sources (21–32, Peale) on the terraces (9th, 12th) of the Hot Springs at Gardiner's River. This color is not entirely due to sky reflection, but partially to the mixed colors of the deposits. A few deposits were iron-rust, drab, yellow, red, &c., and these were always semi-plastic coatings, (silica just deposited,) which, as they became exposed to the air, hardened. Sometimes the mouths at the bottom were oblique, cavernous-looking holes. A few are surrounded by walls a few feet high, and evidently are, or were, geysers. One spring, (102°,) evolving only carbonic-acid gas, differed from the rest in its sides, not sloping toward its center, but uniformly away from it and under its banks, and was apparently bottomless.

In the most active (geyser) space, the surface surrounding each basin or geyser for 100 yards or more is composed of white, scaly, siliceous deposits, is mound-shaped, gently rising a few feet, and only broken here and there by water trickling down. Frequently at the base there are traces of little basins, something like those at Gardiner's River; at the top they exist whole, but never more than 3 to 4 inches deep, thus in some measure giving to the whole a terraced appearance. The top contains the spring or geyser, averaging in this basin 10 to 30 feet across, irregularly shaped, often like the contour of the human ear, and bordered generally by a corrugated elevation of 2 to 3 inches of various beautiful and brilliant colors. On looking into the limpid water from the rim one can see that he is standing on a thin projecting shelf. The water is constantly boiling and steaming in one or two places, and bubbling great gas globules over the rest of the surface; these were carbonic acid and sulphureted hydrogen. In one case I succeeded in taking the temperature when the geyser was in action, throwing water 30 feet, and found it to be 200°.

In the Lower Basin there are very few springs with rims elevated more than 2 to 3 inches; one, however, was about 12 feet high, dome-shaped, having no water visible, but constantly puffing steam, and only intermittingly ejecting water 5 feet. In all cases in both basins where so great a deposit had formed as to hide from view the water, the internal border of the orifice was composed of from 4 to 10 beautiful rounded surfaces covered with little crystals of white, yellowish, drab, &c.; sometimes surrounding the base of these are small holes, vent probably, giving issue to steam and an occasional spurt of water.

The water of the geyser mentioned above (30 feet) contained silica, iron, alumina, lime, magnesia, (trace of,) sulphates, carbonates, chlorides, and sulphides. A specimen brought home to obtain the quantity of silica for the purpose of comparing with a like specimen from the Upper Basin was unfortunately lost.

The Upper Geyser Basin differed from the Lower in greater activity and larger deposits. As the manner and periods of eruptions of geysers have been described and noted, and as our stay was so brief that few observations only could be taken, I refer you to these descriptions: Doane's, Barlow's, Hayden's, &c., and to Prof. T. B. Comstock's collated tables.*

"Old Faithful," the most notable for its having furnished the best opportunities for transient observations, ejects water containing .14 grammes silica to the litre,† lime, a very small quantity of iron, alumina, and magnesia, carbonates, sulphides, chlorides. The pools at the base of its mound are filled with water, lowering between the eruptions to 70°, while those about the vent (containing pebbles) retain a great deal of heat, varying according to proximity. In some of the latter, just previous to an eruption, the thermometer showed 122°, 130°, 138°.

The water of a spring or geyser, (not determined,) at the opening of

* *Vide* Scientific Value of Yellowstone Park, by T. B. Comstock, B. S., Geologist, &c., in American Naturalist, vol. viii, February, 1874.

† The geyser water of Iceland contains 5.40 parts of silica in 10,000 parts of water, the remainder of the total (10.75) constituents being soda principally, (2.74.) In all Yellowstone geysers this base appears to be replaced by lime, there being traces only of soda.

the Upper Basin on the trail along Firehole River, with a drab, nodular deposit, contained iron and alumina, magnesia, carbonates, chlorides, and sulphides, but no trace of lime.

By analysis the geyserites of the Upper Basin do not differ essentially from each other in the quantity of silica they contain; the loss on ignition, however, is comparatively small when the specimen is old or taken from the lower layers. *Vide* Doctors Endlich's and Peale's analyses in Hayden's Report for 1872. The results obtained from four analyses since our return are nearly the same as those. I think it, therefore, proper to note only that one of my specimens, a piece which was found broken off for some time from the rim of a little geyser near the "Giantess," and lying loose some distance from it, with a velvety, drab surface and interior of pearly luster, lost on ignition 6 per cent., and contained 93 per cent. of silica. It thus closely resembles in analysis the opaloid, stratiform specimen No. 2 of Doctor Peale, (p. 154 Hayden's Report 1872,) though in description is more like No. 1. However, it has only traces of iron, the remainder consisting of magnesia and lime.

Camp 48, August 28, on west shore of Yellowstone Lake. Two miles of the shelving beach here are filled with thermal springs, which extend a mile back of the lake, with characters generally like those in the Firehole Valley. Many of them are walled high, or are on conical eminences—two perfect ones in the waters of the lake, some distance from shore. The temperatures range from 70° to 180°, and all evolve carbonic acid; a few only, sulphureted hydrogen. One (80°) whitish-water, like slaking lime, clay-colored deposit, and slightly acid, contained silica, (very little,) iron, alumina, lime, magnesia, sulphates, sulphides, and chlorides. Another, near it, (160°,) evolves water, drab deposit, slightly acid, reacted only for iron and alumina, sulphates, and chlorides. Another, (100°,) with reddish-brown, soft, gelatinous, follicular deposit, evolving carbonic acid, contained soda, lime, magnesia, iron, alumina, silica, sulphides, chlorides, and sulphates. This group can be classed with the springs of the Firehole Valley; whether any active geysers are among them has not been determined.

In our course around the southern shore of the lake and up the Yellowstone River there were no springs except pure mountain, among them the source of "Two-Ocean Pass."

On the picturesque slopes of the Snake River sources occurred many springs, but of no especial interest. The springs at Heart Lake were not visited. On the north side of the fork of Wind River, which we followed to Camp Brown, was (September 8) a small, cold, sulphurous spring, like those in the foot-hills of the Wind River Mountains at Camp Brown.

In conclusion, the difficulties of field analyses in so new and interesting a section as the Yellowstone Basin will be remembered. The imperfect means of transportation (pack-animals) for instruments was often a not unforeseen cause of disappointment and annoyance in all the departments of science represented. As an instance, you will recollect the previously-prepared means to measure the gases at the sources, and in failure thereof to imprison them for subsequent laboratory inspection. Both efforts were fruitless: the first on account of breakage of glassware long before our entrance into the valley; the second for the reason that the manner of collecting and sealing in the open air was not well understood by myself, and though repeatedly tried was only partially successful—so little, I ought to say, that it was always found worthless in result, estimating the exact quantity of free gas. The importance of a correct knowledge of this is appreciated not only by medical hydrologists, but more so, probably, by geologists and physicists; for no one who has witnessed the character of geyser-action can fail to suspect an immense influence of subterranean gases (especially carbonic acid) as a motive-power.

Moreover, before starting, through the kindness of Surg. J. B. Brown, U. S. A., medical director of this department, reagents of all kinds—a complete outfit—were supplied for qualitative analyses; for it was very well known that quantitative analyses could not be made on account of our rapid transit and the abundance of material. Indeed, much more than was required was taken with us, and, consequently, much that under the circumstances became a useless burden: several experiences, in other words, are necessary to select what is necessary. In this connection, should any new student in this field (open-air chemistry, under similar circumstances) desire to know what is or is not requisite, I will be glad to furnish him the needed data, since, after discovering the unwelcome facts, I took pains to note wants and superfluities. However, in anticipation of imperfect work, means were suspected and amply taken to bring back waters, deposits, &c. Of the waters (60 specimens in pints) only 20 were brought unbroken to the Union Pacific Railroad, and these, through some oversight or unexpected delay, were all frozen and rendered worthless before reaching Omaha. As an instance, one specimen of geyser-water from the Lower Basin, brought for the purpose of comparison (silica) with that of the Upper Basin, had frozen and was mostly lost, and what remained had deposited all of its silica, as no reaction for it could be obtained.

In consequence of these difficulties experienced, and many others unforeseen, of the great scientific value in innumerable respects of the Yellowstone region, I fear that much that is now passing there will remain unobserved until such times as the permanent residence of observers is secured by appropriations by the Government, and their material preserved likewise by a properly-paid superintendency.

Chemical analysis comes in particularly for mention in assistance to geology* and to medical hydrology, a much-neglected branch of medicine in the United States, except when for the benefit of this or that corporation or landholder.

From my own imperfect analyses, I would classify the thermal points of the Yellowstone Basin as follows, premising that no definite system (prevalence of an acid, gas, or base) has been copied,† and that the numerous springs in the localities mentioned are merely generalized and do not exclude some with them possessing other characters:

For the localities see context.

Neutral and containing— 1. Carbonic acid and Sulphureted hydrogen.	Turbid Lake. East shore of Yellowstone Lake. Eight miles from Orange Creek.
Acid and 2. Sulphureted hydrogen only.	Opposite head of Yellowstone River. Cañon (falls) east side of river. Orange Creek springs, six miles from Orange Creek.

* *Vide* Geology of Northwestern Wyoming, by Theo. B. Comstock, B. S., American Journal of Science and Arts, vol. vi, December, 1873.

†Barrault—Eaux minerales—is probably the best to use because the latest.

Eaux:

1. Chlorines Sodiques, (6 divisions.)
2. Bicarbonates, (3 divisions.)
3. Sulphates, (4 divisions.)
4. Sulphureuses, (2 divisions.)
5. Ferrugineuses, (4 divisions.)

Others, like Dunglison, (Dictionary, art. Waters, Mineral,) or Nysten, (Dictionnaire de Médicine, &c., art. Eaux minerales,) classify, 1. Gaseous or acidulous. 2. Chalybeate. 3. Saline. 4. Sulphureous.

3. Iron, marked.	Pelican Creek springs, six miles from its mouth.
Lime and 4. Carbonic acid, marked.	Gardiner's River.
Carbonic acid 5. and silica, marked.	Geyser region (Fire Hole Valley,) west side Yellowstone Lake.

From a therapeutic point of view, as there is no recognized system attainable, and elaborate chemical (quantitative) analyses and medical observations are necessary, it is difficult to make comparisons with other well-known sources. Barrault says that "the appreciation of springs is like the science of physiognomy; two sources may have the same constituents in close proportions without being identical from a therapeutical point. In consequence, every analysis must be considered only as relative. Nevertheless, the chemical constituents of a water, the prevalence of one element over another, its temperature, *balneo-thera peutical* means, the climatology of its position, are very valuable indices to the physician in the selection of a water." In this connection Nysten (Dictionnaire art. cit.) remarks of sulphureted waters particularly, that they are the most difficult to imitate, and although their composition is now well known, nevertheless there is something outside of chemical analysis which is not understood, for the manufactured waters do not have exactly the same effect as the natural.

I made several attempts to experiment on the effects of different springs, but as the time allowed was short, nothing was determined.

Gardiner's River springs (external use) seemed to alleviate chronic rheumatism, and, no doubt, would by protracted use cure some forms (syphilitic ?) of dermatoses; both believed by residents and the invalid visitors from Montana.

However, taking the points mentioned by Barrault, I would suggest the probable relation of the following springs to well-known sources:

1. All those which emit carbonic-acid and sulphureted-hydrogen gas, (lose sulphureous principle on keeping,) to Aix-la-Chapelle. Meinberg, (Lippe-Detmold,) in chemical constitution, but not in thermality. Virginia springs, (White Sulphur.)

2. All those which give off sulphureted hydrogen in great quantity, to Bariges, Canterets, Bagnols, (Lozère.)

3. Iron-marked, to all sulphated chalybeate springs, except in temperature, as none but cold springs of this class exist elsewhere.

4. Carbonic acid and silicia-marked, to Rockbridge springs (Virginia) in constituents and effects.

5. Lime and carbonic acid, to Carlsbad, (Bohemia,) in thermality and effects, as the incrustating base of the latter is soda instead of lime. In constituents to Saint Galmier, (Loire.)

By all patients advised or inclined to be hydropathically treated, it is thus seen that the Yellowstone Basin offers all the means, as far as chemical constitution is concerned, with the exception of the unproven existence of manganese, bromine, iodine, and arsenic. The latter element was more than once suspected, but in the hurry tests for all were, unfortunately as the event showed, reserved for a more thorough laboratory analysis. The infinity of springs in all parts, and their great flow, their variety of temperature, any shade of which can easily be got at different points from their source, the facility for all methods of treatment, (inhalation, water-bath, vapor-bath, drinking, douches, &c.,) are remarkable—probably no resort in the world comparing with this region.

A few objections only occur: one, that of the hygienic action of the position. This is defined by Barrault as the influence of altitude, climate, temperature, (relation to water,) &c.

Reference to the meteorological tables will explain the unfitness of this region except for *non-debilitating* diseases, those of the cutaneous and lymphatic systems of the skin, scrofulous (but not tubercular) disorders, rheumatisms, and articular maladies. For asthmatic diseases, bronchial catarrhs, and some forms of dyspepsia; for phthisis, malarial sequelæ, &c., it is evidently inappropriate, and for an additional reason, that of the debilitating result of even a few days' inhalation of the sulphureous air about springs—a constantly-noted fact by many members of your party. At present there is one other objection, remediable, that of the expensive accessibility to invalids of this basin, this to be corrected only by a direct road from the Union Pacific Railroad, and suitable measures for their retention.

Very respectfully, your obedient servant,

C. L. HEIZMANN,
Assistant Surgeon U. S. A.

Capt. W. A. JONES, *U. S. Engineers.*

BOTANICAL REPORT.

BY DR. C. C. PARRY.

LIST OF PLANTS COLLECTED.

DEAR SIR: The following comprises a list of the plants collected on the route of the Northwestern Wyoming expedition, under your command, during the season of 1873.

The numbers affixed are those under which the collection has been distributed to the principal *herbaria* of this country and Europe.

A general sketch of the botanical features of the country passed over, with notices of rare plants and descriptions of the new species collected on the expedition, has been published by your permission in the American Naturalist, being included in consecutive numbers of vol. viii, for January, February, March, and April, 1873.

Respectfully, your obedient servant,

C. C. PARRY.

Capt. W. A. JONES,
Engineer Corps, U. S. A.

DAVENPORT, IOWA, *April* 1, 1874.

BOTANICAL LIST.

No. 1. *Clematis Douglasii*, Hook., Camp Stambaugh, June.
No. 2. *Aquilegia flavescens*, Watson, Yellowstone Park, August.
Aquilegia cærulea, Torr., Owl Creek range, July.
No. 3. *Aquilegia Jonesii*, n. sp., Owl Creek range, July.
No. 4. *Delphinium Menziesii*, DC., Fort Bridger, June.
No. 5. *Delphinium azureum*, Michx., Wind River, July.
No. 6. *Ranunculus occidentalis*, Nutt., Little Sandy, June.
No. 7. *Ranunculus flamula*, L., Stinkingwater, July.
No. 8. *Ranunculus glaberrimus*, Hook., Stinkingwater, July.
No. 9. *Anemone multifida*, DC., Owl Creek, July.
No. 10. *Trollius laxus*, Salisb., Wind River range, July.
No. 11. *Myosurus minimus*, L., Snake River, September.
No. 12. *Thalictrum alpinum*, L., Wind River range, July.
No. 13. *Stanleya tomentosa*, n. sp., Owl Creek, July.
No. 14. *Stanleya viridiflora*, Nutt., Wind River, July.
No. 15. *Draba ventosa*, Gray, n. sp., Snake Pass, September.
No. 16. *Draba alpina*, var. *densifolia*, Pacific Springs, June.
No. 17. *Smelowskia calycina*, Mey., Stinkingwater divide, August.
No. 18. *Arabis canescens*, Nutt., var., Sweetwater, June.
No. 19. *Sisymbrium junceum*, Bieb., Green River, June.
No. 20. *Vesicaria alpina*, Nutt., Green River, June.
No. 21. *Vesicaria Ludoviciana*, DC., Wind River, July.
No. 22. *Capsella divaricata*, Walp., Little Sandy, June.
No. 23. *Lepidium montanum*, Nutt., South Pass, June.
No. 24. *Thelypodium sagittatum*, Endl., Fort Stambaugh, June.
No. 25. *Physaria didymocarpa*, Hook., Red Cañon, July.

No. 26. *Nasturtium lyratum*, Nutt., Yellowstone, August.
No. 27. *Subularia aquatica*, L., Yellowstone Lake, August.
No. 28. *Arabis Drummondii*, Gray, Stinkingwater Pass, August.
No. 29. *Sisymbrium canescens*, Nutt., Stinkingwater, August.
No. 30. *Arabis canescens*, Nutt., Stinkingwater, August.
No. 31. *Draba alpina*, L., Stinkingwater, August.
No. 32. *Cleome aurea*, Hook., Green River, June.
No. 33. *Viola Nuttallii*, Pursh, Wind River, July.
No. 34. *Viola Nuttallii*, var., Stinkingwater, August.
No. 35. *Arenaria Franklinii*, Dougl., Wind River, July.
No. 36. *Arenaria Hookeri*, Nutt., Wind River, July.
No. 37. *Arenaria congesta*, Nutt., Wind River, July.
No. 38. *Arenaria pungens*, Nutt., Stinkingwater, July.
No. 39. *Arenaria arctica*, Steven, Owl Creek, July.
No. 40. *Arenaria Rossii*, R. Br., Owl Creek range, July.
No. 41. *Cerastium arvense*, L., Owl Creek, July.
No. 42. *Lychnis Drummondii*, Watson, Owl Creek, July.
No. 43. *Lychnis Ajanensis*, Regel., Owl Creek range, July.
No. 44. *Spraguea umbellata*, Torr., Stinkingwater, August.
No. 45. *Lewisia rediviva*, Pursh, Wind River, July.
No. 46. *Calandrina pygmæa*, Gray, Wind River, July.
No. 47. *Calyptridium roseum*, Watson, Green River, June.
No. 48. *Sphæralcea acerifolia*, Nutt., Snake River, September.
No. 49. *Rhamnus alnifolius*, L. Her., Stinkingwater, July.
No. 50. *Lathyrus linearis*, Nutt., Wind River, July.
No. 51. *Thermopsis fabacea*, var., *montana*, Gray, Big Sandy, June.
No. 52. *Lupinus pusillus*, L., Green River, June.
No. 53. *Lupinus minimus*, Doug., var., Stinkingwater, August.
No. 54. *Lupinus sericeus*, Pursh, (?) Wind River, July.
No. 55. *Lupinus argenteus*, Watson, Wind River, July.
No. 56. *Lupinus argenteus*, var., Yellowstone, August.
No. 57. *Lupinus cæspitosus*, Nutt., Stinkingwater, July.
No. 58. *Lupinus cæspitosus*, Nutt., var., Yellowstone Falls, August.
No. 59. *Hedysarum boreale*, Nutt., Owl Creek range, July.
No. 60. *Hedysarum Mackenziei*, Rich., Wind River, July.
No. 61. *Trifolium gymnocarpon*, Nutt., Green River, June.
No. 62. *Trifolium Andinum*, Nutt., Ham's Fork, June.
No. 63. *Trifolium longipes*, Nutt., Sweetwater, June.
No. 64. *Trifolium dasyphyllum*, T. and G., Wind River, July.
No. 65. *Astragalus ventorum*, n. sp., Gray, Wind River, July.
Astragalus megacarpus, Gray, Camp Brown, July.
No. 66. *Astragalus sericoleucus*, Gray, Wind River, July.
No. 67. *Astragalus triphyllus*, Pursh, Owl Creek, July.
No. 68. *Astragalus simplicifolius*, Gray, Green River, June.
No. 69. *Astragalus cæspitosus*, Nutt., Stinkingwater, July.
No. 70. *Astragalus Missouriensis*, Nutt., Wind River, July.
No. 71. *Astragalus glabriusculus*, Gray, Wind River, July.
No. 72. *Astragalus lotiflorus*, Hook., Wind River, July.
No. 73. *Astragalus Geyeri*, Gray, Green River, June.
No. 74. *Astragalus Purshii*, Doug., Green River, June.
No. 75. *Astragalus flavus*, Nutt., Green River, June.
Astragalus Grayi, n. sp., Stinkingwater, July.
No. 76. *Astragalus pubentissimus*, Nutt., Green River, June.
No. 77. *Astragalus Shortianus*, Nutt., Green River, June.
No. 78. *Astragalus hypoglottis*, L., Green River, June.
No. 79. *Astragalus glareosus*, Dougl., Green River, June.

No. 80. *Astragalus junceus*, Nutt., Green River, June.
No. 81. *Astragalus campestris*, Nutt., var., Dry Sandy, June.
No. 82. *Astragalus microcystis*, Gray, Stinkingwater, July.
No. 83. *Astragalus microcystis*, var., Stinkingwater, July.
No. 84. *Astragalus oroboides*, Hornem., Stinkingwater, July.
No. 85. *Astragalus Kentrophyta*, Gray, Stinkingwater, July.
No. 86. *Oxytropis campestris*, L., var., Green River, June.
No. 87. *Oxytropis campestris*, L., var., Yellowstone, August.
No. 88. *Oxytropis campestris*, L., var.(?), Owl Creek, July.
No. 89. *Oxytropis viscida*, Nutt.(?), Wind River, July.
No. 90. *Oxytropis Lamberti*, Pursh, Wind River, July.
No. 91. *Oxytropis Lamberti*, Pursh, var., Yellowstone, August.
No. 92. *Oxytropis lagopus*, Nutt., Pacific Springs, June.
No. 93. *Spiræa betulæfolia*, Pallas, Yellowstone, August.
No. 94. *Spiræa cæspitosa*, Nutt., Owl Creek range, July.
No. 95. *Purshia tridentata*, DC., Pacific Springs, June.
No. 96. *Ivesia Gordoni*, Gray, Stinkingwater Pass, August.
No. 97. *Potentilla Plattensis*, Nutt., Stinkingwater Pass, August.
No. 98. *Parnassia fimbriata*, Banks, Stinkingwater, July.
No. 99. *Heuchera cylindrica*, Dougl., Stinkingwater, July.
No. 100. *Saxifraga Jamesii*, Torr., Owl Creek range, July.
No. 101. *Saxifraga debilis*, Engel., Owl Creek range, July.
No. 102. *Mitella trifida*, Grah., Stinkingwater, July.
No. 103. *Tellima tenella*, Benth. & Hook., Sweetwater, June.
No. 104 *Ribes cereum*, Dougl., Sweetwater, June.
No. 105. *Ribes lacustre*, L., Yellowstone, August.
No. 106. *Ribes setosum*, Dougl., Yellowstone, August.
No. 107. *Ribes leptanthum*, Gray, Wind River, July.
No. 108. *Ribes viscossissimum*, Pursh, Yellowstone, August.
No. 109. *Ribes bracteosum*, Dougl., Wind River, July.
No. 110. *Epilobium alpinum*, L., Stinkingwater, July.
No. 111. *Œnothera Andina*, Nutt., Green River, June.
No. 112. *Œnothera scapoidea*, Nutt., Green River, June.
No. 113. *Œnothera breviflora*, Nutt., Yellowstone, August.
No. 114. *Œnothera cæspitosa*, Nutt., Green River, June.
No. 115. *Zauschneria Californica*, Presl., Stinkingwater, July.
No. 116. *Bupleurium Ranunculoides*, L., Yellowstone, August.
No. 117. *Cymopterus montanus*, Nutt., Green River, June.
No. 118. *Carum Gardineri*, Benth. & Hook., Stinkingwater, July.
No. 119. *Peucedanum leiocarpum*, Hook., Yellowstone, August.
No. 120. *Peucedanum* ———, (?), Stinkingwater, August.
No. 121. *Ligusticum scopulorum*, Gray, Yellowstone, August.
No. 122. *Cymopterus anisatus*, var., Gray, Wind River, July.
No. 123. *Cymopterus Fendleri*, Gray, Green River, June.
No. 124. *Valeriana dioica*, L., Stinkingwater, July.
No. 125. *Kellogia galeoides*, Torr., Stinkingwater, July.
No. 126. *Aster Parryi*, n. sp., Gray, Green River, June.
No. 127. *Aster pulchellas*, D. C. Eaton, Yellowstone, August.
No. 128. *Aster adscendens*, Lindl., Yellowstone, August.
No. 129. *Aster montanus*, Rich., Snake River Pass, September.
No. 130. *Aster conspicuus*, Lindl., Yellowstone, August.
No. 131. *Aster integrifolius*, Nutt., Yellowstone, August.
No. 132. *Machæranthera canescens*, Gray, Yellowstone, August.
No. 133. *Aster elegans*, Nutt., Yellowstone, August.
No. 134. *Aster Engelmanni*, Gray, Yellowstone, August.
No. 135. *Erigeron ursinum*, D. C. Eaton, Yellowstone, August.

No. 136. *Erigeron compositum*, Pursh, Green River, June.
No. 137. *Erigeron radicatus*, Hook. (?), Wind River, July.
No. 138. *Erigeron radicatus*, Hook., var. (?), Wind River, July.
No. 139. *Erigeron canescens*, Hook., Wind River, July.
No. 140. *Erigeron concinum*, T. and Gr., Green River, June.
No. 141. *Solidago Virga-aurea*, L., Yellowstone, August.
No. 142. *Townsendia spathulata*, Nutt., Wind River, July.
No. 143. *Townsendia strigosa*, Nutt., Wind River, July.
No. 144. *Townsendia Parryi*, n. sp., D. C. Eaton, Wind River, July.
No. 145. *Townsendia spathulata*, var. (?), Stinkingwater Pass, August.
Townsendia condensata, n. sp., Washake's Needles, July.
No. 146. *Chænactis Douglasii*, H. and A., Green River, June.
No. 147. *Chrysopsis hispida*, Hook., Yellowstone, August.
No. 148. *Bahia Cucophylla*, DC., Stinkingwater, July.
No. 149. *Aplopappus inuloides*, Nutt., Wind River, July.
No. 150. *Schkuria integrifolia*, n. sp., Gray, Wind River, July.
No. 151. *Grindelia squarrosa*, Dunal., Wind River, July.
No. 152. *Rudbeckia occidentalis*, Nutt., Snake River, September.
No. 153. *Arnica Parryi*, n. sp., Gray, Yellowstone, August.
No. 154. *Arnica angustifolia*, var. (?), Yellowstone, August.
No. 155. *Arnica angustifolia*, var. (?), Fort Stambaugh, June.
No. 156. *Arnica longifolia*, D. C. Eaton, Snake River Pass, September.
No. 157. *Actinella acaulis*, Nutt., Stinkingwater, July.
No. 158. *Actinella grandiflora*, T. and Gr., Wind River, July.
No. 159. *Cosmidium gracile*, T. and Gr., Green River, June.
No. 160. *Tetradymia canescens*, var. *inermis*, Nutt., Green River, June.
No. 161. *Aplopappus suffruticosus*, Gray, Yellowstone, August.
No. 162. *Aplopappus acaulis*, Gray, Green River, June.
No. 163. *Aplopappus Nuttallii*, T. and Gr., Wind River, July.
No. 164. *Aplopappus multicaulis*, Gray, Wind River, July.
No. 165. *Balsamorhiza Hookeri*, Nutt., Pacific Springs, June.
No. 166. *Balsamorhiza sagittata*, Nutt., Wind River, July.
No. 167. *Senecio amplectens*, var. *taraxicoides*, Gray, Yellowstone, Aug.
No. 168. *Senecio Fremontii*, Gray, Stinkingwater, July.
No. 169. *Senecio canus*, Hook., Yellowstone, August.
No. 170. *Senecio Andinus*, Nutt., Yellowstone, August.
No. 171. *Senecio lugens*, Rich., Yellowstone, August.
No. 172. *Antennaria dimorpha*, Nutt., Green River, June.
No. 173. *Antennaria dioica*, Gaertn., Owl Creek, July.
No. 174. *Antennaria luzuloides*, Torr. and Gray, Stinkingwater, July.
No. 175. *Antennaria alpina*, Gærtn., var. (?), Stinkingwater, July.
No. 176. *Antennaria Carpathica*, R. Br., Wind River, July.
No. 177. *Antennaria racemosa*, Hook., Stinkingwater, July.
No. 178. *Tanacetum capitatum*, Nutt., Wind River, July.
No. 179. *Tanacetum Nuttallii*, T. and Gr., Wind River, July.
No. 180. *Artemesia pedatifida*, Nutt., Green River, June.
No. 181. *Artemesia spinescens*, D. C. Eaton, Green River, June.
No. 182. *Artemesia incompta*, Nutt., Owl Creek, July.
No. 183. *Artemesia scopulorum*, Gray, Yellowstone, August.
No. 184. *Artemesia Ludoviciana*, Nutt., var., Yellowstone, August.
No. 185. *Troximon parviflorum*, Nutt., Green River, June.
No. 186. *Macrorrhynchus glaucus*, D. C. Eaton, Green River, June.
No. 187. *Troximon aurantiacum*, Hook. (?), Green River, June.
No. 188. *Hieracium Scouleri*, Hook., Yellowstone, August.
No. 189. *Stephanomeria paniculata*, Nutt., Stinkingwater, July.
No. 190. *Crepis accuminata*, Nutt., Wind River, July.

No. 191. *Crepis occidentalis*, Nutt., Wind River, July.
No. 192. *Porterella carnulosa*, Torr., Yellowstone, August.
No. 193. *Bryanthus Empetriformis*, Gray, Stinkingwater, July.
No. 194. *Ledum glandulosum*, Nutt., Yellowstone, August.
No. 195. *Gaultheria Myrsinites*, Hook., Yellowstone, August.
No. 196. *Monotropa hypopothys*, L., Yellowstone, August.
No. 197. *Lonicera cœrulea*, L., Yellowstone, August.
No. 198. *Pyrola dentata*, Hook., Yellowstone, August.
No. 199. *Dodecatheon Meadia*, L., Wind River, July.
No. 200. *Androsace filiformis*, L., Yellowstone, August.
No. 201. *Androsace Chamajasme*, L., Owl Creek, July.
Douglasia montana, Gray, Washakee's Needles, July.
No. 202. *Phelipæa lutea*, n. sp., Owl Creek, July.
No. 203. *Phelipæa fasciculata*, Nutt., Owl Creek, July.
No. 204. *Pentstemon Menziesii*, Hook., Stinkingwater, August.
No. 205. *Pentstemon Menziesii*, Hook., var., Snake Pass, September.
No. 206. *Pentstemon laricifolius*, H. and A., Owl Creek, July.
No. 207. *Pentstemon deustus*, Dougl., Stinkingwater, July.
No. 208. *Pentstemon gracilis*, Nutt., Pacific Springs, June.
No. 209. *Pentstemon secundiflorus*, Benth., Yellowstone, August.
No. 210. *Pentstemon humilis*, Nutt., Pacific Springs, June.
No. 211. *Pentstemon glaucus*, Graham, Stinkingwater, July.
No. 212. *Mimulus Lewisii*, Pursh, Stinkingwater, July.
No. 213. *Mimulus moschatus*, Dougl., Stinkingwater, July.
No. 214. *Eunanus Fremontii*, Gray, Yellowstone, August.
No. 215. *Pedicularis Parryi*, Gray, var. (?), Yellowstone, August.
No. 216. *Castilleia breviflora*, Nutt., Stinkingwater, July.
No. 217. *Castilleia flava*, Watson, Stinkingwater, July.
No. 218. *Orthocarpus Parryi*, n. sp., Gray, Yellowstone, August.
No. 219. *Castilleia affinis*, H. and A., Nebraska, June.
No. 220. *Echinospermum deflexum*, Lehm., Yellowstone, August.
No. 221. *Echinospermum deflexum*, Lehm., var., Yellowstone, August.
No. 222. *Myosotis alpestris*, L., Stinkingwater, July.
No. 223. *Myosotis alpestris*, L., var., Stinkingwater, July.
No. 224. *Myosotis alpestris*, L., var., Yellowstone, August.
No. 225. *Eritrichium villosum*, var. *aretioides*, DC., Wind River, July.
No. 226. *Mertensia alpina*, Don., Stinkingwater, July.
No. 227. *Mertensia alpina*, Don., var., Stinkingwater, July.
No. 228. *Eritrinchium glomeratum*, DC., var. (?), Green River, June.
No. 229. *Phacelia circinata*, Jacq., Stinkingwater, July.
No. 230. *Phlox bryoides*, Nutt., Pacific Springs, June.
No. 231. *Phlox canescens*, T. and Gr., Green River, June.
No. 232. *Phlox Douglasii*, Hook., Owl Creek, July.
No. 233. *Phlox longifolia*, Nutt., Green River, June.
No. 234. *Gilia liniflora*, Benth., Stinkingwater, July.
No. 235. *Gilia nudicaulis*, Gray, Wind River, July.
No. 236. *Gilia pungens*, Benth., var., Green River, June.
No. 237. *Gilia inconspicua*, Dougl., Green River, June.
No. 238. *Gilia congesta*, Hook., Green River, June.
Gilia iberidifolia, Benth., Green River, September.
No. 239. *Gilia spicata*, Nutt., Green River, June.
No. 240. *Gilia Breweri*, Gray, Dry Sandy, June.
No. 241. *Colomia gracilis*, Dougl., var., Green River, June.
No. 242. *Polemonium confertum*, Gray, Wind River, July.
No. 243. *Polemonium parvifolium*, Nutt., Stinkingwater, July.
No. 244. *Swertia perennis*, L., Yellowstone Falls, August.

No. 245. *Gentiana detonsa*, Fries., Yellowstone, August.
No. 246. *Asclepias brachystephana*, Torr., Green River, June.
No. 247. *Acerates viridiflora*, Ell., Owl Creek, July.
No. 248. *Polygonum imbricatum*, Nutt., Stinkingwater, July.
No. 249. *Rumex paucifolius*, Nutt., Sweetwater, June.
No. 250. *Eriogonum flavum*, Nutt., Owl Creek, July.
No. 251. *Eriogonum brevicaule*, Nutt., Wind River, September.
No. 252. *Eriogonum ovalifolium*, Nutt., Green River, June.
No. 253. *Oxytheca dendroidea*, Nutt., Big Sandy, June.
No. 254. *Paronychia sessilliflora*, Nutt., Wind River, July.
No. 255. *Shepherdia argentea*, Nutt., Wind River, September.
No. 256. *Eleagnus argenteus*, Nutt., Green River, September.
No. 257. *Comandra pallida*, DC., Wind River, July.
No. 258. *Atriplex endolepis*, Watson, ined., Stinkingwater, July.
No. 259. *Grayia polygaloides*, H. and A., Green River, June.
No. 260. *Kochia prostrata*, Schrad., Green River, September.
— — *Suæda depressa*, Pursh, Green River, September.
No. 261. *Atriplex canescens*, Watson, ined., Green River, June.
No. 262. *Betula occidentalis*, Hook., Green River, June.
No. 263. *Salix* ———(?), Wind River, July.
No. 264. *Juniperus Sabina*, var. *procumbens*, Pursh, Owl Creek, July.
No. 265. *Calochortus Eurycarpus*, Watson, Yellowstone, August.
No. 266. *Fritillaria atropurpurea*, Nutt., Wind River, July.
No. 267. *Fritillaria pudica*, Spreng, Yellowstone, August.
No. 268. *Spiranthes Romanzofiana*, Cham., Yellowstone, August.
No. 269. *Allium brevistylum*, Watson, Yellowstone, August.
No. 270. *Allium Schœnoprasum*, L., Yellowstone, August.
No. 271. *Allium Schœnoprasum*, L., Yellowstone, August.
No. 272. *Allium reticulatum*, (Watson, 1181,) Sweetwater, June.
No. 273. *Allium cernuum*, Roth, Owl Creek, July.
No. 274. *Allium reticulatum*, Fras., Green River, June.
No. 275. *Juncus xiphioides*, E. Mey., Yellowstone, August.
No. 276. *Carex Douglasii*, Boott., Fort Bridger, June.
No. 277. *Carex Raynoldsii*, Dewey, Yellowstone, August.
No. 278. *Carex vitilus*, Fr., Yellowstone, August.
No. 279. *Carex aquatilis*, Wahl., Yellowstone, August.
No. 280. *Carex rigida*, Good., Yellowstone, August.
No. 281. *Carex Hoodii*, Boott., Wind River, July.
No. 282. *Carex festiva*, Dewey, Yellowstone, August.
No. 283. *Carex Douglasii*, Boott., Stinkingwater, July.
No. 284. *Carex tenuirostris*, Olney, ined., Yellowstone, July.
No. 285. *Carex vulgaris*, Fries., Yellowstone, August.
No. 286. *Carex Jamesii*, Torr., Yellowstone, August.
No. 287. *Carex leporina*, L., Stinkingwater, July.
No. 288. *Eriophorum polystachyon*, L., Yellowstone, August.
No. 289. *Kœleria cristata*, Pers., Yellowstone, August.
No. 290. *Poa*, ———, (?), Yellowstone, August.
No. 291. *Tristeum subspicatum*, Beauv., Stinkingwater, July.
No. 292. *Agrostis scabra*, Willd., Yellowstone, August.
No. 293. *Festuca* ———, (?), Yellowstone, August.
No. 294. *Poa tenuifolia*, Nutt. (?), Yellowstone, August.
No. 295. *Melica bulbosa*, Geyer, Yellowstone, August.
No. 296. *Beckmannia cruciformis*, Host., Stinkingwater, July.
No. 297. *Elymus condensatus*, Pursh, Wind River, July.
No. 298. *Poa Andina*, Nutt., Yellowstone, August.
No. 299. *Triticum œgilipoides*, Turck., Yellowstone, August.
No. 300. *Calamagrostis Lapponica*, Trin. (?), Yellowstone, August.

FILICES.

No. 301. *Cheilanthes lanuginosa*, Nutt., Owl Creek, July.
No. 302. *Cystopteris fragilis*, Benth, Yellowstone Falls, August.
No. 303. *Woodsia scopulina*, D. C. Eaton, Yellowstone, August.
No. 304. *Woodsia Oregana*, D. C. Eaton, Sweetwater, June.
No. 305. *Botrychium lunaroides*, L., Yellowstone, August.
No. 306. *Botrychium simplex*, Hitchcock, Yellowstone, August.

LYCOPODIACEÆ.

No. 307. *Isoëtes Bolanderi*, n. sp., Engel., Yellowstone, August.

FUNGI.

No. 308. *Trichobasis leguminosarum*, Lk., Wind River, July.
No. 309. *Æcidium Ranuncalacearum*, DC., Wind River, July.
No. 310. *Æcidium Psoraleæ*, n. sp., C. H. Peck, Colorado, June.
No. 311. *Æcidium Parryi*, n. sp., C. H. Peck, Stinkingwater, August.

ENTOMOLOGICAL REPORT.

BY J. D. PUTNAM.

DEAR SIR: The following list embraces the *Coleoptera* collected during the months of June, July, and August, 1873, on the route from Fort Bridger to the Yellowstone National Park, via Green River, South Pass, Camp Brown, Wind River, and Stinkingwater River; and on the return, in September, via Snake and Wind Rivers. My opportunities for collecting were quite limited, having responsible meteorological duties to perform at all times, and being almost constantly on the march. For these reasons, and also on account of the lack of transportation facilities, the collections are much more imperfect than they should have been. All the regions passed through, and especially the Wind River district, give promise of good yields for future collectors. I am much indebted to the officers on the survey for various kindnesses, and to Mr. Henry Ulke, who very kindly determined the *Coleoptera*, hereafter enumerated, for me. I also annex a list of words used by the Shoshone Indians to designate insects.

Respectfully, your obedient servant,

J. D. PUTNAM.

Capt. W. A. JONES,
United States Corps of Engineers.

LIST OF COLEOPTERA.

Cicindella tranquebarica, Herbst, =*vulgaris*, Say, Green River basin, June.

C. duodecimguttata, Dej., Yellowstone basin, August.

Elaphrus Californicus, Mann., Green River basin, June.

Nebria hudsonica, Lec., Yellowstone basin, August.

Calosoma luxatum Say, Wind River basin, June.

Carabus Agassii, Lec., variety of *C. tædatus*, Fort Bridger, May; Wind River and Stinkingwater, July.

Lebia guttula, Lec., Wind River basin, July.

Philotecnus nigricollis, Lec., Green River basin, June.

Pterostichus protractus, Lec., Fort Bridger, May; Yellowstone basin, August.

Pt. Luczotii, Dej., Fort Bridger, May.

Amara lacustris, Lec., Fort Bridger, May.

A. patricia, Dej., Yellowstone basin, August.

Chlænius sericeus, Forster, Green River basin, June.

Harpalus amputatus, Say, Green River basin, June.

H. funistus, Lec., Fort Bridger, May; Yellowstone basin, August.

H. stupidus, Lec., Fort Bridger, May.

H. furtivus, Lec., Fort Bridger, May.

H. obesulus, Lec., Green River basin, June.

Bembidium nebraskense, Lec., Yellowstone basin, August.

B. lucidum, Lec., Green River basin, June.

B. umbratum, Lec., Green River basin, June.
Dytiscus marginicollis, Lec., Yellowstone basin, August.
Silpha lapponica, Herbst, Fort Bridger, May.
S. ramosa, Say, Wind River basin, June.
Aleochara bimaculata, Grav., Green River basin, June.
Creophilus villosus, Grav., Yellowstone basin, August.
Philonthus, (undetermined,) Fort Bridger, May.
Saprinus pratensis, Lec., Green River basin, June.
Phalacrus pennicillatus, Say, Green River basin, June ; Wind River, July.
Nitidula ziczac, Say, Wind River basin, July.
Dermestes marmoratus, Say, Green River basin, June.
D. caninus, Germ., Green River basin, June.
Aphodius denticulatus, Hald., Green River basin, June.
Trox alternans, Lec., Fort Bridger, May.
Hoplia laticolis, Lec., Wind River basin, July.
Serica curvata, Lec., Wind River basin, July.
S. frontalis, Lec., Wind River basin, July.
Lachnosterna fusca, Fröhl., Fort Bridger, May.
Polyphylla decemlineata, Say, Owl Creek, July.
Melanophila longipes, Say, Stinkingwater Valley, July ; Yellowstone basin, August.
Acmæodera mixta, Lec., Wind River basin, July ; abundant in the flowers of the prickly pear, (*Opuntia*.)
Brachys terminans, Fabr., Wind River basin, July.
Dolopius pauper, Lec., Stinkingwater Valley, July.
Corymbites tinctus, Lec., black variety, Yellowstone basin, August.
Podabrus, (undetermined,) Stinkingwater Valley, July.
Collops vittatus, Say, Green River basin, June.
C. cribrosus, Lec., Green River basin, June.
Pristoscellis, near *fuscus* Lec., Wind River basin, July.
Listrus interruptus, Lec., Wind River basin, June.
Dolichosoma foveicollis, Kirby, Wind River basin, July.
Dasytes breviusculus, Motsch., Green River basin, June.
Eleodes obscura, Say, Wind River basin, July.
E. hispilabrus, Say, Green River basin, June; Wind River basin, July.
E. extricata, Say, Green River basin, June; Wind River basin, June. July.
E. nigrina, Lec., Green River basin, June.
E. pimelioides, Mann., Wind River basin, July.
Blapstinus pratensis, Lec., Green River basin, June.
Cœlocnemis dilaticollis, Mann., Yellowstone basin, August.
Corphyra lugubris, Say, Yellowstone basin, August.
C. Lewisii, Horn, Wind River basin, July.
Notoxus serratus, Lec., Wind River basin, July.
N. subtilis, Lec., (?) Green River basin, June.
Anaspis rufa, Say, Wind River basin, July.
Epicauta puncticollis, Mann., Wind River basin, June.
E. maculata, Say, Wind River basin, July.
E. sericans, Lec., Wind River basin, June, July.
Lytta fulgifera, Lec., variety of *Nuttalli*, Say, Wind River basin, July.
Cephaloon lepturides, Newm., variety, Yellowstone basin, August.
[Mr. Ulke says, "Your specimens differ in size and coloration from the Northern-Atlantic types, but I have an intermediate form from Oregon."]
Prionus Californicus, Motsch., Stinkingwater basin, July.

Criocephales productus, Lec., Yellowstone basin, August.
Cr. asperatus, Lec., Yellowstone basin, August.
Monohammus scutellatus, Say, Wind River basin, July.
Oxoplus corallinus, Lec., Yellowstone basin, August.
[Differs from Mr. Ulke's New Mexico type in having the base of the elytra blackish.]
Pachyta liturata, Kirby, Yellowstone basin, August.
Acmæops pratensis, Laich.,=*strigilata*, Fabr., Wind River basin, July.
Ac. subpilosa, Lec., Wind River basin, June.
Galeruca americana, Fabr., Green River basin, June.
Luperus longulus, Lec., Wind River basin, June, July.
Haltica (*Graptodera*,) *inærata*, Lec., Green River basin, June.
Disonycha alternata, Ill., Wind River basin, July.
Saxinus saucia, Lec., Wind River basin, July.
Adoxus vitis, Linn., Wind River basin, July.
Trirhabda alternata, Say, var., Yellowstone basin, August.
Monoxia guttulata, Lec., Green River basin, June.
Hippodamia Lecontei, Muls., Green River basin, June.
H. quinquesignata, Muls., Wind River basin, July.
H. parenthesis, Say, Green River basin, June.
Coccinella picta, Rand., Yellowstone basin, August.
C. trifasciata, Linn., Wind River basin, July; Yellowstone basin, August.
C. transverso-guttata, Fald., Yellowstone basin, August.
C. novemnotata, Herbst., Green River basin, June; Wind River basin, June.
Sphenophorus Ulkei, Horn., Green River basin, June.
Lepyrus colon, Linn., Wind River basin, July.

There were also collected five or six undescribed species of *Curculionidæ*, belonging to the genera *Listroderes*, *Lichenophagus* (?), and *Erirhinus*.

INDIAN NAMES FOR INSECTS.

The following words, used by the Shoshone or Snake Indians to designate insects, were obtained September 14, 1873, at Camp Brown, Wyoming Territory, from Moonharvy, Charlie, and Bob, three Shoshone Indians belonging to Washakie's band:

Large, wingless cricket, (*Anabrus simplex*, Hald.,) Mesch.
Black cricket, (*Gryllus* ——, sp. ?), Mesch; Mes-oo-wan-ich.
Spider-like cricket, (*Stenopelmatus ?*) Nen-i-gúipo.
Pupa of a large grasshopper, (*Œdipoda*,) Át-tung.
Large grasshopper, (*Œdipoda*,) A-dún-ich.
Hateful grasshopper, (*Calaptenus spretus*, Uhler,) Ud-sée-guee.
Tenebrionidæ, (*Cœlœnemus dilaticollis*, Mann,) Bee-sóu-guah.
Cerambycidæ, *Prionus Californicus*, Motsch.,) Gōn-i-pée-ah.
Green buprestid, E-wée-et.
Horse-fly, (*Tabanus*,) Bée-meet.
Common fly, (*Musca*,) (An-é-vou,) An-é-ou.
Tremex, (sp. ?) An-e-góot-tsee.
Cicada, (sp. ?) Kü-ah.
Ant-lion (*Myrmelion*,) Es-poú-see.
Day-fly, (*Ephemera*,) Moó-pō.
Various diurnal butterflies and moths, A-e-pril.
Colias philodice, (yellow,) Oabit A-e-pril.
Moths, from Washakie's Needles, (*Arctia*,) Un-dwust.
Large, brown caterpillar, (larva of some *Sphingidæ*,) Beer-waub.

Colors.

White, Tós-it-eh.
Black, Ton-ór-wit.
Brownish-black, Toú-gon-daú-bit.
Brown, Toú-gon-umph.
Red, En-ga-bit.
Yellow, [Oabit,] Orbt.
Green, Á went.
Blue, (bright,) Tsoi-wú-it.
Blue, (grayish,) Ah-mú-it.